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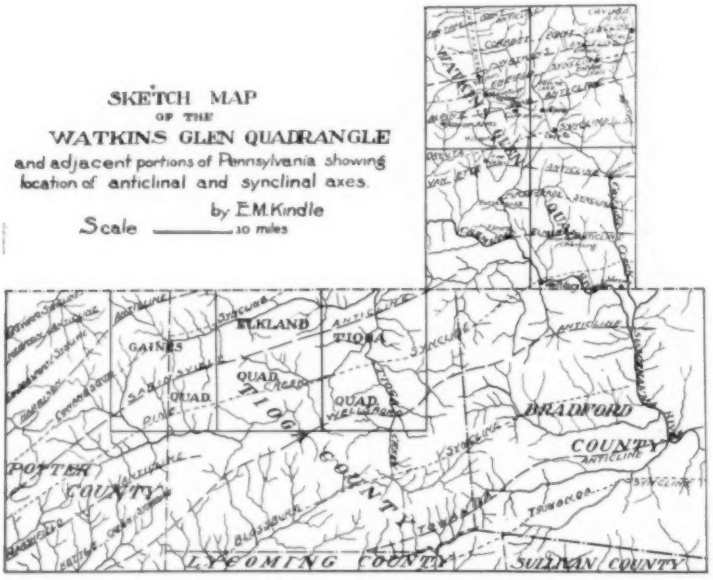
A SERIES OF GENTLE FOLDS ON THE BORDER OF THE APPALACHIAN SYSTEM.[1]

THE conclusions of this paper have been reached in the study of the Watkins Glen quadrangle, New York. This quadrangle comprises the four fifteen-minute quadrangles known as the Watkins, Ithaca, Elmira, and Waverly quadrangles. Extending from the Pennsylvania state line to the Seneca and Cayuga Lake valleys, it includes the southern portion of each. This area lies immediately north of the region of the Appalachian folds. The surface rocks of the quadrangle are the shales and sandstones of the Chemung, Portage, and Genesee formations. The rock strata over much of the area vary so little from the horizontal position that the dip can usually be recognized only by the very careful use of the clinometer or the level. Dips high enough to be conspicuous, and ranging from 8 to 55°, have been noted occasionally in various parts of the quadrangle, but these high dips have in nearly all cases been found to be associated with small local anticlines or faults, extending frequently only a few rods and possessing only local interest. With these higher dips the present paper is not concerned; but the interpretation of the more obscure dips ranging usually from 1 to 3 or 4° will be attempted.

A careful study of the low dips characterizing the rocks over the major part of the quadrangle has shown them to have an important structural significance. They have been found to represent a series of low, approximately parallel, anticlinal folds, having the same general direction as the great mountain folds immediately south of them in Bradford county, Pennsylvania.

[1] Published by permission of the director of the U. S. Geological Survey.

Very gentle dips ranging from ½ to 5°, but rising in a few instances to 10° or more, characterize these folds. Although very low, they belong to anticlinal folds, which are very persistent. Some of them have been traced entirely across the quadrangle. Five of these folds, separated by a corresponding number of synclines, have been recognized. Beginning at the north, the folds will be designated by the



following names: the Fir Tree Point anticline, the Watkins anticline, the Alpine anticline, the Van Etten anticline, and the Elmira anticline. The position of these minor folds with reference to the nearest Allegheny folds is shown by the accompanying sketch map.[1]

Fir Tree Point anticline.—This fold has a width along Lake Seneca of five and one-half miles. The axis crosses the lake at Fir Tree Point, two and a half miles south of the northern edge of the quadrangle, bearing a little north of east. Nearly continuous

[1] The location of the Pennsylvania folds shown by the map is based upon maps published in the *Pennsylvania State Geological Reports* and in *Folio No. 93*, U. S. Geological Survey.

exposures of the rock in the lake shore cliffs on each side of the anticlinal axis, as far as the synclinal axes limiting the arch make it possible to measure accurately the total height of the arch by noting the thickness of the successive beds as they rise above the lake level. Measured in this way, the crest of the anticline is found to rise about 115 feet above the troughs of the synclines on each side. This anticline therefore brings to view 115 feet of strata which are below lake-level at the northern edge of the quadrangle. This includes about 75 feet of typical Portage sandstones and shales, and some forty feet of black and dark gray shales which represent the transition between the Portage and the Genesee, corresponding to the Middlesex shales of Clarke and Luther.

The north dips terminate at the synclinal axis crossing the lake on the east side at the edge of the quadrangle north of Peach Orchard and just north of Glenora on the west side. The axis of the Corbett's Point syncline to the south of this fold crosses the lake just north of Corbett's and Cottage Points, three miles south of the anticlinal axis. The amount of the north and south declinations of this fold along Seneca Lake are practically the same, but its axis is a half-mile nearer to the synclinal axis on the north than it is to the synclinal axis on the south, so that the inclination of the north limb is somewhat greater than that of the south limb.

It is very probable that the anticline crossing Lake Cayuga in the vicinity of Shurger Point, which has a maximum elevation of 235 feet on the east side and 160 feet on the west side,[1] is the northeastern continuation of the Fir Tree Point anticline, but the continuity of the two has not been verified by a study of the dips in intervening territory. Along Lake Cayuga, south of Shurger's Point south dips continue until the synclinal axis at Ithaca is reached, the rate of dip being about 110 feet per mile.

Watkin's anticline.—Six miles south of Fir Tree Point a second, but much lower, fold crosses the south end of Lake Seneca. Its axis crosses the lake just north of Watkins, six miles south of Fir Tree Point. Continuing eastward by northeast, it crosses the Cayuga Inlet valley in the southern edge of Ithaca. The maximum height of the fold above the syncline on the north is about 35 feet. A band

[1] *American Journal of Science*, Vol. XXVI (1883), p. 304.

of heavy-bedded sandstone outcropping at the foot of the cliffs just below the entrance to Watkins Glen affords a convenient datum plane from which to determine the height of the Watkins fold. This is the only band of sandstone exceeding 10 or 12 inches in thickness in this part of the section, and it is easily followed from its outcrop north of Salt Point, where its base is only a few inches above lake level to Watkins, where it reaches its maximum elevation of 30 feet above the lake in a ravine just north of the village.

This sandstone band dips below lake-level about 500 yards north of Salt Point. From the point where it disappears to the axis of the syncline the north dip does not exceed 10 feet, so that the total rise of the fold above the Corbett Point syncline is probably between 35 and 40 feet. On the east side of the lake the maximum elevation of the fold, which is about 10 to 12 feet less than on the west side, is attained at the quarry just north of Excelsior Glen. From this point, where the band of massive sandstone mentioned above is 20 feet above lake-level, the dip is very gentle to the north, the sandstone band reaching lake-level at the north side of "Painted Rocks," about one mile north of Excelsior Glen. South of Watkins the Watkins Glen sandstone is seen at the base of the quarry half a mile below town. A short distance south of this point it dips below the level of the marsh.

At Ithaca the very gentle north dips of this fold are seen along the west side of the Inlet valley from the south edge of town nearly to the lake. The much heavier south dips appear in South Hill. The south dips of this fold both at Ithaca and Watkins greatly exceed the north dips. The synclinal axis between this fold and the next on the south passes a little north of Montour Falls and Lake Cayuta, through the village of Enfield and out of the quadrangle east of the upper dam in Buttermilk Creek.

Alpine anticline.—The strongest fold in the quadrangle is the next one south of the Watkins fold and running parallel with it. The axis of this fold enters the quadrangle nearly west of Beaverdams. Passing a little north of Beaverdams and south of Moreland, it crosses Catherine Creek valley about five miles south of the head of Seneca Lake, and Cayuta Creek one mile north of Alpine. The axis crosses Cantor Creek one and a half miles north of Pony Hollow; passing

between Newfield and Stratton, it continues northeasterly to the edge of the quadrangle. Continuing this axis into the Dryden quadrangle, in the same direction which it follows in the Ithaca quadrangle, it joins the anticline which in the vicinity of Brookton is represented by southerly dips of 5 to 6°.

The northerly dips of the Alpine anticline usually vary between 1 and 2°. North dips as high as 3° have, however, been observed in the quarry in Odessa, and along Cayuta Creek one mile south of Cayuta Lake. The south dips are much stronger than the north dips, and vary from 3 to 10°. Northeast of Chambers south and southeasterly dips of from 3 to 8° are seen. In the ravine east of Alpine half a mile the dips range from 8 to 10° in a southeasterly direction. Just west of West Danby the south dips vary from 3 to 6°. The average south dip for this fold is probably $3\frac{1}{2}$ or 4°.

It will be noted that the total south dip in this quadrangle of the rocks to the north of the axis of the Alpine anticline is very small. The much greater inclination of the beds to the south of this axis over those to the north of it makes the effective south dip along the southern edge of this fold much greater than elsewhere in the quadrangle, and explains the abrupt appearance of the Chemung in all of the hills on the south flank of this fold.

The synclinal axis to the south of this fold enters the region about a mile south of the northwest corner of the Elmira quadrangle. Passing northeasterly through Millport, it crosses Cayuta Creek just south of Cayuta and leaves the quadrangle about one mile north of the Chemung-Tompkins county line.

Van Etten anticline.—The axis of this fold crosses Cayuta Creek at Van Etten. Bearing a little to the north of west, it crosses Catherine Creek about a half-mile south of Pine Valley, thence, trending a little south of west, it passes just north of Catherine, and probably leaves the quadrangle to the west of Quackenbush Hill. The north and south dips of this fold may be seen along nearly all of the streams which it crosses. The dips of the north limb of the fold are particularly well displayed in the outcrops along Dry Run, Langford Creek, and Cayuta Creek. The dips of the south limb of the fold may be seen along Dean Creek, Cayuta Creek, Baker Creek, and a number of other small streams to the south of the axis, varying usually from 2 to 3°.

The synclinal axis south of the Van Etten fold crosses Cayuta Creek apparently about two and three-quarters miles north of Reniff. Its position has been recognized just east of Horseheads, but west of this point the complexity of the dips renders the determination of its course uncertain.

The Elmira anticline.—The axis of the southernmost anticlinal fold in the quadrangle runs eastward from about the abrupt southerly bend of the Chemung River east of Elmira; passing south of North Chemung and just north of Chemung Centre, it crosses Cayuta Creek just north of Lockwood. At Lockwood the north limb of the anticlinal has flattened until the dip cannot be detected by the clinometer or hand-level, but there is probably a very small north dip for two and one-half or three miles up the valley to the point where the south dips of the Van Etten fold cease. In the western half of the Waverly quadrangle the north dips are pronounced along Baldwin Creek northeast of North Chemung and its tributaries to the west of North Chemung. The north dip at the quarries east and north of Elmira, which averages about 2°, may be observed nearly to Horseheads. The south dips of this fold along the east side of the Chemung River range from 3 to 5° south or southeast. The south dips east of this may be seen along nearly every south-flowing stream to the eastern edge of the Waverly quadrangle. The course of the fold west of Elmira is not entirely clear. Sherwood recognized the Elmira anticline as a continuation of a Pennsylvania fold and states that "it crosses the Chemung River a little below Elmira."[1] Sherwood states that he "has seen no dips beyond Elmira and Horseheads."[2] Heavy southwest dips for two miles along the river west of the city and also north of the summit of Hawley Hill indicate the probability, as suggested by Mr. M. L. Fuller, that the axis bends to the north, west of Elmira, passing between Hawley and Hawes Hills. Thence, bending southward, it probably joins the Sabinsville anticline near the southwestern corner of the quadrangle.

The syncline to the south of the Elmira anticline is well defined in the southeastern part of the Waverly quadrangle. The axis crosses Cayuta Creek about three miles north of Waverly. Passing westward between Shoemaker Mountain and Narrow Hill, it crosses

[1] *Report G*, Pennsylvania Geological Survey, p. 95. [2] *Ibid.*, p. 96.

the Chemung River to the north of Wellsburg. Apparently it bears sharply to the southwest near this point and joins the Pine Creek syncline of Pennsylvania. While the connection between the Pine Creek and Narrow Hill synclines has not been clearly established, the rather abrupt eastward bend of the former, which follows, if they are continuous, is in harmony with the sudden change in the trend of the Wellsburg anticline and the Blossburg syncline on the south from northeast to east.

It appears certain that the comparatively insignificant structural features which have been described are of the same age and origin as the great open folds of the northern Alleghenies. In the quadrangle cornering with the Watkins Glen quadrangle on the southwest are folds whose arches, if restored, would rise 2,500 feet above their troughs.[1] Less than twenty miles to the south of the Watkins Glen quadrangle another great fold shows a crest of similar or greater elevation. From theoretical considerations it would appear improbable that the effects of the epirogenic forces which have developed structures of such magnitude should terminate abruptly at the northern edge of the highly folded belt. Instead of abrupt change from highly folded to monoclinal or nearly horizontal structure, we find the mountain flexures subsiding gradually into the low, gentle swells which have been described. This may be illustrated by a comparison of the maximum dips exhibited by the anticlinal folds encountered between South Mountain in Bradford county, Pennsylvania, and the southern end of Lake Seneca. Eighteen miles south of the Watkins Glen quadrangle runs the axis of the Towanda anticline between two synclinal mountain ridges—Mount Pisgah and South Mountain. Dips of 70° or more have been observed on the south side of this anticline, but the average dip for the belt of maximum inclination is approximately 40°. The dips of the north limb of this fold are very much lower than the south dips. The writer, although familiar with the region, has not observed any dips which will exceed 20°, and the dips in the zone of maximum inclination will probably not average more than 15°. It is noteworthy that the great excess of the south dip over the north dip of this fold is a characteristic common to nearly all folds of the Watkins Glen quadrangle.

[1] *Folio No. 93*, U. S. Geological Survey, p. 5.

The next anticlinal axis north of the Towanda anticline approaches to within about six miles of the southern edge of the Watkins Glen quadrangle. This anticline, which is known as the Wellsburg anticline, does not differ greatly, as developed in Bradford county, from the Alpine anticline of the Watkins Glen quadrangle in the magnitude of the dips, which seldom exceed 5° in Bradford county. The latter has, however, less than half the width of the Wellsburg anticline, which accounts for the failure of the Alpine anticline to develop synclinal mountain ridges, such as those associated with the Wellsburg fold. In the Elmira fold, which is the next fold north of the Wellsburg syncline, the maximum dips have dropped to 2° for the north limb and about 3 or 4° for the south limb. The Watkins, fold, which is about fifteen miles north of the Elmira fold, may be cited as showing the smallest dips of any fold in the quadrangle, the maximum amounting to 1° or less.

It follows as a result of the anticlinal structure which has been described that the total southerly declination of the beds of the quadrangle, amounting to several hundred feet, is not the result of a regular or approximately uniform rate of dip to the south per mile, as has been generally assumed.[1] On the contrary, the rocks rise toward the south on the north side of each of the axes described. The dip of the south limb of the fold is, however, as stated above, usually greater than the north dip. In the case of the Alpine anticline the south dip is very much greater than the north dip, the result being that the total of the south dips in the quadrangle considerably exceeds the north dips, and that any given horizon at the south side of the quadrangle is several hundred feet lower than at the north side.

Between the south end of Lake Cayuga and Newfield the north and south dips about balance each other, the beds of a given horizon being at nearly the same level at these two points. The same is

[1] Since completing the field work on which this paper is based, the writer's attention has been called to a paper by Professor H. S. WILLIAMS (*Proceedings of the American Association for the Advancement of Science*, Vol. XXXI (1882), p. 412), which gives a brief description of folds corresponding to the eastern portion of some of those herein described. Hall observed the north dips between Elmira and Horseheads in 1839, and states that the rocks rise "southward from Horseheads to the Chemung River." (*Third Annual Report, Fourth Federal District*, p. 323.)

true of the dips of the beds in the Seneca Lake valley—similar horizons lying as high or higher at the axis of the anticlinal fold two miles south of Montour Falls as at Cottage Point eight miles north. On crossing the axis of the Alpine anticline, however, a south dip ranging from 3 to 8° brings the beds very rapidly toward sea-level.

The various maps of the New York State Survey, which cover portions or the whole of this region, have evidently been constructed on the supposition of an approximately uniform southerly dip in the region about the southern ends of the Seneca and Cayuga Lake basins. As a consequence, the Chemung-Portage parting, as shown on these maps, involves an inaccuracy of several miles in many places. In the "Finger Lakes Sheet," and the revised state map published in 1901, the northern limit of the Chemung between the Seneca and Cayuga basins is drawn about ten miles south of its actual northern limit, while the Portage has been found by the writer above drainage several miles south of the southern limit shown by the map.

The conclusions stated above have, as shown, been reached through a study of the stratigraphy, but supplementary paleontologic work has been found to confirm them throughout. The writer has found typical Chemung fossils at the northern edge of the Watkins quadrangle, about ten miles north of the northern limit of the Chemung, as given by the New York state map for that meridian. Due east of Ithaca, *Spirifer disjunctus* has been found in the higher beds, which have heretofore been supposed to belong to a Portage terrane and which lie about seven miles north of the Portage-Chemung boundary for that region, according to the New York state map.

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THE LARAMIE AND FORT UNION BEDS IN NORTH DAKOTA.

WHILE considering economic problems in North Dakota and eastern Montana, abundant opportunity was given to examine the beds that in geological literature have long been known as the Fort Union, and to compare them with beds that have been assigned without question to the Laramie. From this study certain definite impressions were gained in regard to the relationship existing between the Fort Union beds and the Laramie. In stating these impressions, no effort will be made to contribute to the already abundant literature bearing on the larger question of the position of the Laramie as a whole.

The field work covered six months in the years 1902 and 1903, the area studied including the entire western half of North Dakota and eastern Montana along the Yellowstone. The unusual exposures along the Missouri throughout the three hundred miles of its course in North Dakota were examined, the trip down the river being made by boat. From the western boundary of North Dakota the river passes from beds that have been regarded as typical Fort Union, to an area that has been assigned without reserve to the Laramie. The tributaries of the Missouri from the west and the bad lands also give abundant opportunity for stratigraphic study.

Though eager to discover vertebrate remains, none were found, except great numbers of buffalo bones in the lower river terraces. Molluscan and plant fossils, however, were collected at a number of points. The molluscs were identified by Mr. T. W. Stanton, and the plants by Mr. F. H. Knowlton, of the U. S. Geological Survey, and those that seem to be suggestive in considering the relation of the Fort Union to the Laramie will be noted.

The area supposed to be occupied by the Fort Union beds has never been definitely outlined. Lesquereaux[1] states that they occupy

> the whole country about Fort Union, extending north into the British possessions to unknown distances; also southward to Fort Clarke; seen under the White River group, on North Platte River, above Fort Laramie; also on west side of Wind River Mountains.

[1] *United States Geological Survey*, Vol. VII, p. 24.

The older reports of the United States Geological Survey locate Fort Union variously in North Dakota and Montana. The place has long since disappeared from the map, and the site is now represented by Fort Buford, which is located on the Missouri River only three miles from the mouth of the Yellowstone. The confusion in regard to states arose from the fact that the old Fort Union, while located in North Dakota, was only three miles from the Montana line.

The following sections, taken at Glass Bluffs, on the south bank of the Missouri and four miles below Fort Buford, illustrates the beds commonly designated as Fort Union.:

			Feet	Inches
	13	glacial drift	25	
	12	gravel, well rounded, fresh	4	
Fort Union	11	clay, sandy	90	
	10	sandstone	2	
	9	clay, blue, sandy	48	
	8	clay	2	
	7	lignite, impure		3
	6	clay	4	
	5	lignite, fair quality	5	
	4	clay, hard, yellow	4	
	3	clay, fat	6	
	2	lignite, good quality, with 3 in. clay in middle	3	6
	1	yellow clay, growing sandy toward the top	35	
			228	9

Instead of being in any way remarkable, this section would serve to illustrate the prevailing characteristics of the Laramie as well as it does the Fort Union. In North Dakota, at least, there is nothing peculiar in the beds, their composition or position, that will differentiate the Fort Union from the Laramie. If a number of descriptions of Laramie sections taken from the Little Missouri country south of Medora, or north of Bismarck were written with sections from about old Fort Union, it is practically certain that the regions from which they came could not be distinguished. A large number of sections like the one just quoted, but taken from regions that have always been regarded as Laramie, have been published elsewhere.[1] In a single area, in the southern part of the state near the mouth of the Cannon Ball River and extending back from the Missouri for sixty miles, the Laramie differs from the so-called Fort Union beds

[1] *Second Biennial Report of the North Dakota Geological Survey*, 1901–2.

about Fort Buford. As exposed along the Cannon Ball River, the Laramie is made up for the most part of sand and sandstone, while lignite is present only in thin beds, and clay is second to sand in abundance. Here, however, *Corbicula nebraskensis* M. & H. is found in abundance, which was originally reported from the Fort Union of the Northwest.

Shells were found in abundance at a number of points, the following forms being frequently noted:

Viviparus trochiformis M. & H.

Campeloma multilineata M. & H.

Unio priscus M. & H.

These were found alike about old Fort Union and in the Laramie, and at various horizons.

At a number of points leaf-prints were found. Ten miles north of Minot and one hundred and twenty miles east of old Fort Union, a clay bed between two lignite seams occurs, filled with the following forms:

Sequoia angustifolia Lesq.

Sequoia Langsdorfii (Brongniart) Heer.

Sequoia brevifolia Lesq.

At least one of these forms was found at Mannhaven, eighty miles north of Mandan. Though the Fort Union has never been definitely outlined, no one seems to have extended it to these points. In these two localities the leaf-prints had a nearly common elevation of 1,600 feet, while the lowest beds exposed on the Missouri River at old Fort Union are 1,800 feet above the sea.

Near Coal Harbor, which is eighty miles north of Bismarck, at an elevation of 100 feet above the Missouri River, and both outside of and below the Fort Union beds, as they are commonly understood, a limestone layer about two feet thick occurs, which abounds in leaf prints. From this limestone the following were taken:

Credneria? daturiaefolia.

Phyllites cupanioides Newb.

Celastrus (probably).

In his note returning the fossils, Mr. R. S. Bassler, of the U. S. National Museum, to whom the specimens were sent, says: "Mr. Knowlton, of the United States Geological Survey, has kindly identified them, and says that their age appears to be Fort Union."

Phyllites cupanioides is noted in Newberry's[1] list as occurring only in the Fort Union.

As a result of two summers of field work in North Dakota, the very definite impression remains that, at least in that state, there is great difficulty in retaining the term "Fort Union beds," since they never have been, and apparently cannot be, set off from the Laramie either in vertical or horizontal extent. The conclusion of White[2] seems to be wholly justified:

> In eastern Montana and western North Dakota the Laramie strata are similarly connected, by specific identity of molluscan remains and by apparent continuity of sedimentation, with those which there are reported to bear a purely Tertiary flora, and which have generally been designated the Fort Union group.

From the standpoint of paleobotany, Clark[3] indicates that the same conclusion may be reached. He quotes Professor Newberry,[4] who held that the two formations should be referred to different horizons, the Laramie to the Cretaceous, and the Fort Union to the Tertiary. These quotations he follows immediately with others from Professor Ward, who, discussing the statements of Dr. Newberry, says:

> that, although the difference in flora exists, "yet the Laramie and Fort Union must go together," and offers in explanation "that possibly the latitude, taken in connection with a different topography, such as may have existed in the two regions, might account for the great difference in the floras." Professor Ward further gives a list of eight identical species from the Laramie and Fort Union groups.

Knowlton[5] also holds that there can be scarcely any doubt that the flora of the Upper Laramie, of the Atanekerdluk series in Greenland, and of the Spitzbergen and Alaskan territories is identical with the Fort Union flora of the Missouri region.

In mapping North Dakota, therefore, there seems to be no satisfactory reason for noting Fort Union beds as distinguished from the Laramie. Indeed, to make such a distinction seems practically impossible.

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April 30, 1904.

[1] Monograph XXXV, *The Later Extinct Floras of North America*, p. 150.

[2] *Bulletin No. 82*, U. S. Geological Survey, p. 149.

[3] *Ibid., Bulletin No. 83*, p. 135.

[4] *Geological Society of America, Bulletin*, Vol. I (1890), pp. 524–27.

[5] *Proceedings of the National Museum*, Vol. XXVII (1894), p. 240.

ORBICULAR GABBRO-DIORITE FROM DAVIE COUNTY, NORTH CAROLINA.[1]

GENERAL STATEMENT.

SPHEROIDAL or orbicular structures have been observed in granites and diorites among plutonic rocks from many parts of the world, and especially celebrated are some of these occurrences in North America and Europe. The best-known of the European localities are Fonni[2] in Sardinia, Wirvik[3] in Finland, Slätmossa[4] in Sweden, Riesengebirge[5] in Silesia, Mallaghderg[6] in County Donegal, Ireland, and Corsica. In America the structure seems to have been less often observed than in Europe, though a number of occurrences have been described, mostly among granites, from widely separated localities. These have been made known through the publications of Edward Hitchcock,[7] Hawes,[8] Chroustschoff,[9] von Rath,[10] Zirkel,[11] Kemp,[12] F. D. Adams,[13] and Lawson,[14] which include the following

[1] Published by permission of the state geologist of North Carolina.

[2] G. VON RATH, *Sitzungsberichte der Niederrheinischen Gesellschaft*, Bonn, June, 1885, p. 201; F. FOUQUE, *Bulletins de la Société mineralogique de France*, Vol. X (1887), p. 57.

[3] B. FROSTERUS, *Tschermaks Mineralogische und petrographische Mittheilungen*, Vol. XIII (1898), p. 177; Bull. Com. Geol. Finland, 1896, No. 4.

[4] W. C. BRÖGGER, OCH H. BÄCKSTRÖM, *Geologiska Föreningen i Stockholm, Förhandlinger*, Vol. IX (1887), p. 351; H. BÄCKSTRÖM, *ibid.*, Vol. XVI (1894), p. 107; N. D. HOLST, OCH F. EICHSTADT, *ibid.*, Vol. VII, p. 134.

[5] F. H. HATCH, *Quarterly Journal of the Geological Society*, Vol. XLIV (1888), p. 548.

[6] G. ROSE, *Poggendorff's Annalen*, Vol. LXI, p. 624.

[7] *Geology of Vermont*, Vol. II (1861), p. 564.

[8] *Geology of New Hampshire*, Vol. III (1878), Part 4, p. 203.

[9] *Bulletins de la Soci'té mineralogique de France*, Vol. VIII (1885), p. 137.

[10] *Sitzungsberichte der Niederrheinischen Geschellschaft für Natur- und Heilkunde*, December, 1, 1884.

[11] *Fortieth Parallel Survey*, Vol. VI (1878), p. 54.

[12] *Transactions of the New York Academy of Sciences*, Vol. XIII (1903), pp. 140–43 *Science*, N. S., Vol. XVIII (1903), p. 503.

[13] *Bulletin of the Geological Society of America*, Vol. IX (1898), p. 163.

[14] A. C. LAWSON, "The Orbicular Gabbro Diorite at Dehesa, San Diego county, California," *The University of California Publications*, Bulletin, Department of

principal localities: the "prune" or "pudding" granite of Craftsbury, Vermont; the orbicular diorite at Rattlesnake Bar, El Dorado county, California; the granite from Clark's Peak, Medicine Bow Range, Colorado; orbicular granite from Quonochontogue Beach, Rhode Island; a spheroidal granite from near Charlevoix, Michigan, in the northwest portion of the Lower Peninsula; a nodular granite from from Pine Lake, Ontario; and the orbieular gabbro at Dehesa, San Diego county, California.

The nodules of spheroidal rocks are considered similar in some respects to the dark segregations, or "schlieren," so frequently observed and described in granites. Like the spheroids, the dark segregations are usually more basic in composition than the general magma out of which they have segregated. A noteworthy exception to this, however, is the nodular granite from Pine Lake, Ontario, described by Adams,[1] the nodules of which are very appreciably more acid than the granite matrix, although the analysis[2] of the matrix indicates a very acid granite. The schlieren of granites in general are often of rounded outline, and at times show a sharp line of demarkation from the inclosing matrix, but, as a rule, they display no tendency to separate from the granite when broken. In many cases the segregations (schlieren) and spheroids are quite similar in mineral composition, but the dark segregations do not manifest the concentric and radiating structures characteristic of the spheroidal nodules.

Last summer (1903), while engaged in field study of the granites of North Carolina for the State Survey, the writer had occasion to examine very carefully in the field an orbicular gabbro-diorite in Davie county,[3] and later to study, microscopically, thin sections cut

Geology, Vol. III (1904), pp. 383–96; abstract, *Science*, N. S., Vol. XV (1902), p. 415.

Some of the references given above on the European localities have not been accessible to me. Those not accessible have been quoted from PROFESSOR KEMP'S paper in the *Transactions of the New York Academy of Sciences*, cited above; and from SIR A. GEIKIE'S *Text Book of Geology*, 1903, 4th ed., Vol. I, pp. 206, 224.

[1] "Nodular Granite from Pine Lake, Ontario," *Bulletin of the Geological Society of America*, Vol. IX (1898), pp. 163–72.

[2] *Ibid.*, p. 169.

[3] Knowledge of the existence of this rock dates back many years, but, so far as I am aware, a full description of it has not been published. Very brief mention of it

from hand specimens of the rock collected. Certain peculiarities of occurrence, structure, and composition of this rock not previously noted, so far as I am aware, among deep-seated rocks developing the spheroidal structure, seemed worthy of careful study. Further interest attaches to this rock for the reason that, as yet, it forms the only example of orbicular structure among deep-seated rocks found in the southern Appalachian region, and also because it adds a rock type which, in some respects, is a new one developing nodular or spheroidal structure.

GENERAL DESCRIPTION OF THE OCCURRENCE.

Exposures of the orbicular rock occur in the eastern part of Davie county on the Hairston farm, about ten miles west of Lexington and within one and a half miles of the Yadkin River. A peak or knoll of moderate size, rising about thirty feet in elevation above the surrounding plain and composed of huge bowlders, affords the only exposure of the fresh rock. Several of the larger bowlders have been split and partially worked off at different times, chiefly for use about the Hairston residence and to a less extent for museum specimens.

Traced southwestward from the knoll is found complete evidence of the extension in that direction of the orbicular gabbro-diorite, in the residual decay and in occasional partially decayed fragments of the rock scattered over the surface. The decay is of a pronounced dark, nearly black color, with a distinct greenish tint imparted by the ferromagnesian constituent of the fresh rock. Oxidation of the iron in the iron-bearing minerals of the decay is not appreciably apparent at any point. As nearly as could be determined, the zone of residual decay derived from the gabbro-diorite averages several hundred feet in width and extends approximately one-half to three-quarters of a mile southwest from the koll. Fairly sharp contacts between the decay of the orbicular diorite and that of an inclosing gray porphyritic biotite granite were noted in a number of places, which strongly suggest that the orbicular rock forms a dike having an approximate northeast-southwest strike, penetrating the porphyritic biotite granite.

is made in the following publications: J. V. LEWIS, "Notes on Building and Ornamental Stone," *First Biennial Report of the State Geologist*, 1891-92, North Carolina Geological Survey, 1893, p. 91; GEORGE P. MERRILL, *Stones for Building and Decoration* (New York, 1897), 2d ed., p. 259.

The field relations between, and the mineral composition of, the diorite and granite suggest different periods of intrusion of the two rocks, in the Carolina locality. Close by and approximately paralleling the general direction in strike (northeast-southwest) of the orbicular gabbro-diorite are some half-dozen dikes of massive unaltered

FIG. 1.

normal diabase which penetrate the porphyritic granite. While conclusive evidence is lacking, it is not improbable that the orbicular diorite and the neighboring dikes of diabase are of the same age. Southwestward a short distance from the knoll of exposed masses of the typical orbicular structure, the rock loses its characteristic nodular or spheroidal structure and assumes a pronounced granitic texture of rather coarse grain, but composed of the same minerals and of the same general dark color.

The color of the orbicular rock is dark, with a greenish tint imparted by the dark green ferromagnesian minerals. As indicated

in Fig. 2, the spheroidal growths compose by far the bulk of the rock. Variation of the nodules is from nearly perfect spheres to ellipsoidal in shape, and in size they range from a fraction of an inch to several inches across. They can readily be broken out of the rock in complete form, almost or entirely free from the inclosing matrix. Compression due to flow movements in the rock while still plastic is but slightly indicated in the shapes of the nodules.

The nodules are uniformly greenish black in color, composed, as a rule, almost or entirely of dark ferromagnesian minerals, which show a radial arrangement about a common center. They are usually crowded close together, touching each other in many cases, with the interspaces largely filled with clear white cleavable and lustrous feldspar, a very little quartz, and penetrating laths of hornblende. Relatively large and small perfect crystals of reddish-brown titanite are very generally distributed through the rock, common to both nodules and matrix. In some instances feldspar and quartz, rarely pyrite, in small grains, have been observed, each in different spheroids, to form a nucleus about which the somewhat fibrous ferromagnesian minerals have arranged themselves in a radial structure. Both the feldspar and the quartz may occur together, forming the nucleus of a single nodule. Of the nucleal minerals feldspar is perhaps the most common. In a majority of the spheroids, however, the nucleus or core of feldspar and quartz practically fails, when the nodules become spheres of ferromagnesian minerals.

Search through the literature develops, from descriptions of orbicular structure in deep-seated rocks, several important differences in structure and composition of the spheroids in the Carolina rock from those usually observed in similar rocks from other localities. The chief differences to be noted are: (1) In the Carolina rock the spheroids are marked by the almost entire absence of concentric structure, which ordinarily characterizes the nodules of deep-seated orbicular rocks described from other localities. Only the barest semblance of such structure is noted in the Carolina rock, and it entirely fails in most of the spheroids. (2) The spheroids of orbicular rocks hitherto described are composed of several minerals, usually the principal constituents of the groundmass, though additional ones

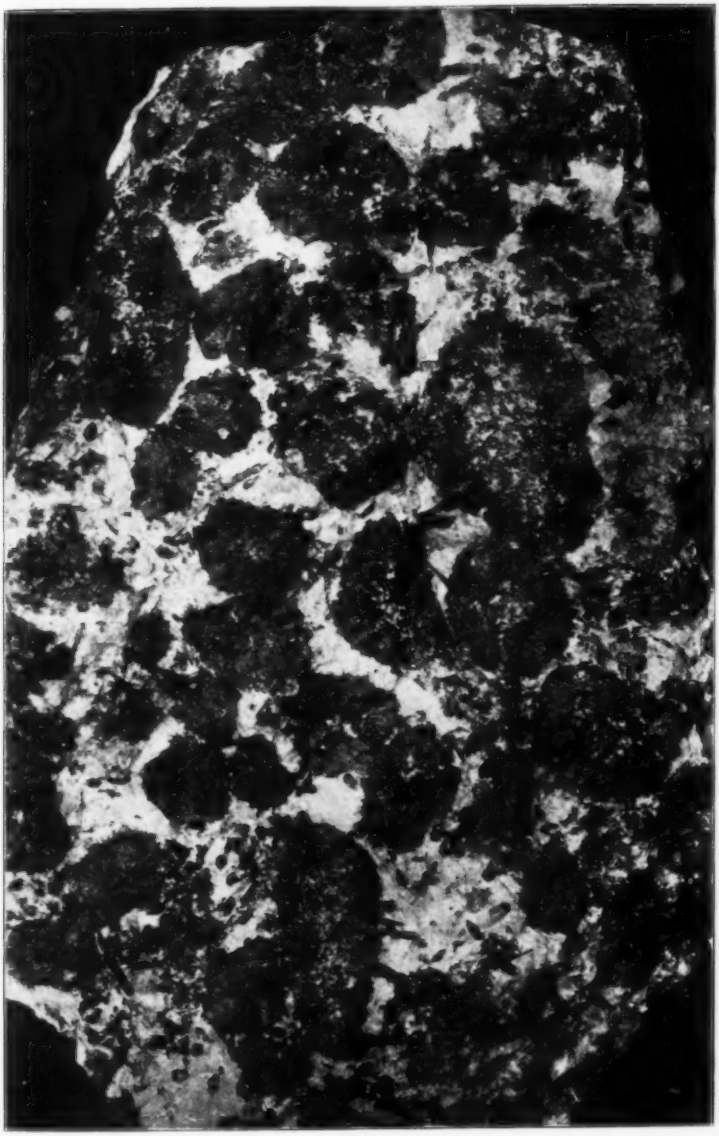

FIG. 2.

not present in the groundmass may occur, in some cases, in the nodules. As would be expected, difference in color for different parts of the spheroid would naturally follow from such a structural arrangement of the differently colored minerals, such as feldspar and quartz with one or more of the dark silicates. In the Carolina rock the spheroids are very generally composed of the dark silicates, in many of which the light-colored minerals, quartz and feldspar, entirely fail, hence they are very basic in composition and are of the same uniformly dark greenish color throughout. The feldspar filling the interspaces is often penetrated by large laths of the black lustrous hornblende, which may either have contact with, or extend from, the spheroid, or be entirely separated therefrom and inclosed wholly by the feldspar. (See Fig. 2.)

MICROSCOPICAL CHARACTER OF THE ROCK.

Six thin sections were prepared from selected chips of the rock for microscopical study. Five of the sections were cut from the nodules and one from a representative fragment of the interstitial filling or matrix. The character of the sections was such that only slight evidence was afforded of the structure of the nodules microscopically, but the radial arrangement of the minerals composing the nodules about a common center is entirely clear in hand specimens of the rock, as indicated in the megascopic description above and shown in Fig. 2.

Diallage, green hornblende, basic plagioclase, microcline, quartz, titanite, muscovite, calcite, zoisite, magnetite, and an occasional zircon are the principal minerals of the rock. Essentially the same minerals are observed, as a rule, in both the matrix and the nodules, but in different proportions; the matrix being composed very largely of feldspar, with very subordinate amount of most of the other minerals, and the nodules of the ferromagnesian minerals, with in many of them only the barest trace of the other minerals. Of the accessory minerals noted in the nodules feldspar is usually in largest amount.

The ferromagnesian minerals, diallage and hornblende, in varying amounts are present in all the sections. In many of them, probably a majority, hornblende is subordinate in amount to diallage; in others the two are in nearly equal proportion; and in still others

hornblende is in slight excess. Diallage occurs in rather large irregular forms without crystal boundaries, exhibiting strong development of the orthopinacoidal cleavage. It is usually of faint greenish color and without sensible pleochroism. Minute microscopic interpositions are abundant, and it further incloses irregular grains and perfect idiomorphic crystals of hornblende.

The hornblende is principally of the green uralitic kind, approximating parallel columnar and fibrous forms, which usually show cleavage only in direction of elongation, but it entirely fails in some of the more irregular aggregates. Both the hornblende and diallage indicate some alteration (leaching) to nearly colorless forms. The angle of extinction measured on many pieces of the hornblende varies from 13° to 20°. Pleochroism is confined chiefly to green tones, with the ray vibrating parallel to A appearing slightly yellow, and that vibrating parallel to B is occasionally tinged a faint brown. Compact hornblende in rhombic cross-sections, bounded by the prism and usually the pinacoid faces, and showing the intersecting prismatic cleavages, is distributed through the sections, with much of it inclosed by the diallage.

Basic plagioclase is the predominant feldspar. Its substance is never fresh, but is largely altered to muscovite and calcite, and some zoisite which, with few exceptions, has completely destroyed the polysynthetic twinning lamellæ. It occurs almost entirely as irregular, large grains without idiomorphic outline. Perfectly fresh microcline as irregular grains, and exhibiting the characteristic twinning structure, is present in every thin section studied. It sometimes occurs as inclusions of moderate-sized grains in the plagioclase. Abundant prisms of apatite, usually of fairly large size, are included in the feldspar. Some of these are in cross-sections which show perfect hexagonal shape; others are in longitudinal sections, and occasionally some of the apatite forms grains of irregular outline.

Titanite is abundant in comparatively large idiomorphic crystals, yielding characteristic, sharply rhombic cross-sections. Some of it occurs in irregular grains without crystal outline. In thin section the color is pale to moderately deep brown, with slight absorption in the deeper-colored crystals. It is usually free from inclusions of other minerals. Cleavage is rather pronounced in much of it.

Quartz is present in very subordinate amount in many of the sections, and it is probably largely, if not entirely, secondary. Muscovite and calcite are wholly secondary, and as such they present no noteworthy features. Magnetite and an occasional zircon complete the list of minerals.

Summing up the results of the microscopic study, we find that the sections consist essentially of diallage, uralitic hornblende, and a basic plagioclase, showing, as a rule, but slight polysynthetic twinning, and usually altered to muscovite and calcite, or to zoisite and muscovite. The presence of perfectly fresh microcline in subordinate amount, a little quartz which is probably secondary, and a relatively large amount of accessory titanite and apatite is characteristic. Clearly the rock is a gabbro-diorite, although the presence in some of the sections of microcline and quartz is unusual.

ORIGIN OF THE NODULAR STRUCTURE.

Bäckström accounts for the origin of certain European nodular granite on the basis of magmatic differentiation, in which the nodules, like the Carolina occurrence, are more basic than the matrix.[1] This seems to be the most satisfactory explanation of the Carolina occurrence, but whether the beginning of the nodules resulted from greater basicity, differential cooling, or from some other cause, it is not possible to state definitely.

From the relations of the minerals in the rock it appears that the dark silicates generally preceded the feldspar in crystallization, although overlapping in the periods of separation from the magma of these minerals is distinctly shown. The primary accessories, apatite, titanite, iron ore, etc., are idiomorphic in outline and were the earliest minerals to crystallize from the magma. Microscopic evidence further indicates that the nodules were developed in the magma when crystallization was fairly well advanced.

RÉSUMÉ.

Briefly summarized, the principal results of this study are: (1) The rock is a gabbro-diorite whose field relations strongly suggest occurrence in the form of a dike penetrating a gray porphyritic biotite

[1] JOURNAL OF GEOLOGY, Vol. I (1893), pp. 773–90; *Geologizka Föreningen i Stockholm, Förhandlingar*, 1894, p. 128.

granite. (2) Two textural facies of the rock having approximately the same mineral composition, are observed, namely, (*a*) orbicular or nodular, and (*b*) granitic. (3) In the nodular facies the nodules compose vastly the greater bulk of the rock. They are of varying, but moderately large, size, usually crowded close together, with a small amount of matrix or interstitial filling, largely composed of feldspar and very subordinate amount of the other minerals. (4) The nodules are uniformly dark in color, very basic in composition, and, with but few exceptions, are made up almost entirely of the dark silicates, diallage, and hornblende. (5) The structure of the nodules is radial and not, as frequently observed in such rocks, concentric, or both. (6) Microscopic evidence suggests that the nodular structure is a product of magmatic differentiation.

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THE OSTEOLOGY OF THE SKULL OF THE PELYCOSAURIAN GENUS, DIMETRODON.

DURING the summer of 1904 the author collected in the Permian beds of Texas two skulls of the genus *Dimetrodon* belonging in the suborder *Pelycosauria*. These skulls were in an excellent state of perfection, which permits the completion of previous descriptions and the correction of some errors.

Especially valuable is the fact of the preservation of the temporal arches, permitting a description of this region, which has been hitherto only partially known and falsely interpreted. The two skulls are numbered 1001, *Dimetrodon incisivus* (?), and 1002, *Dimetrodon gigas*, of the University of Chicago collection of fossi vertebrates. The specimen of *Dimetrodon gigas* was almost perfectly preserved, only a portion of the temporal arches of the left side and the middle portion of the epipterygoid being lost. The larger part of the following description is taken from it; some details, and the description of the lower jaws, are added from specimen 1001.

As shown in Fig. 1, the skull has proportions much like those of the modern lizards or the carnivorous Dinosaurs. The eyes are not located so far back in the head, and the facial region, while elevated, does not bear the great disproportion to the skull shown in previous restorations.[1]

The quadrate of *Naosaurus* was correctly interpreted by Cope as an elevated element similar to the same bone in the modern *Sphenodon*. This was later denied by Baur and Case,[2] and the statement was made that the quadrate was a depressed bone completely surrounded by the bones of the temporal region, and in this regard similar to the African Theriodonts.

[1] E. D. COPE, "On the Homologies of the Posterior Cranial Arches of the Reptilia," *Transactions of the American Philosophical Society*, Vol. XVII (1892); G. BAUR AND E. C. CASE, "On the Morphology of the Skull of the *Pelycosauria* and the Origin of the Mammals," *Anatomische Anzeiger*, Vol. XIII (1897), pp. 109–20; *idem.*, "The History of the *Pelycosauria*, with a Description of the Genus *Dimetrodon*," *Transactions of the American Philosophical Society* (2), Vol. XX (1899), pp. 1–58.

[2] *Op. cit.*

The determination was made on a partially preserved skull of *Dimetrodon incisivus*, and a series of unfortunate conclusions have been drawn from this erroneous determination. The present specimens show that Cope was correct in his determination of the quadrate as an elevated bone, and also demonstrates its remarkable similarity in position and relations to the quadrate of *Sphenodon*.

Figs. 1, 2, and 4 show the general form and relation of the quadrate. It is an elevated, thin plate of bone ending freely above, articu-

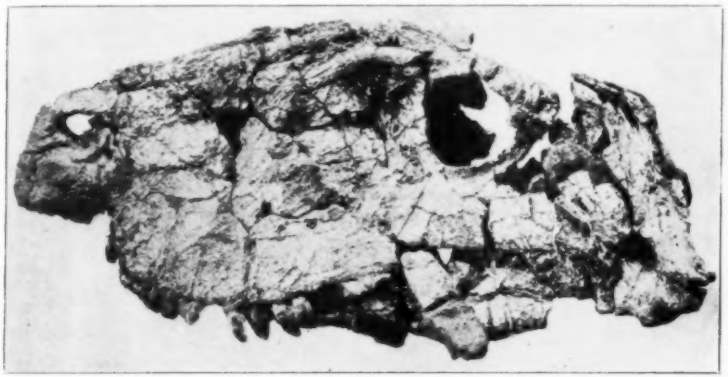

FIG. 1.—Left side of the skull of *Dimetrodon gigas*. About one-fourth natural size. Full length of skull, 46 cm.

lating with the pterygoid anteriorly, and the quadrato-jugal, squamosal and paroccipital posteriorly. The lower end is terminated by two elongate articular condyles, which run almost parallel antero-posteriorly, but are slightly convergent anteriorly. The inner condyle stands out from the side of the bone, and its inner side articulates with the posterior end of the pterygoid. The outer condyle projects beyond the posterior edge of the bone, and its upper surface is flat, forming a sort of shelf, to the upper side of which is articulated the lower end of the quadrato-jugal.

The quadrato-jugal is a very slender plate of bone that articulates with the posterior edge of the quadrate for its full length. Above, the quadrato-jugal passes between the squamosal and prosquamosal, and articulates with the parietal; below, it is separated from the quadrate by a fair-sized quadrate foramen.

Anterior to the quadrato-jugal is another element in the position usually assigned to the quadrato-jugal; *i. e.*, it articulates with the jugal anteriorly and passes back to articulate with the quadrate region. It is separated from the quadrato-jugal posteriorly (which is identified beyond doubt by the presence of the quadrate foramen) by a distinct suture, and occupies the exact position of the anterior portion of the squamosal of the living *Sphenodon*. It is separated from

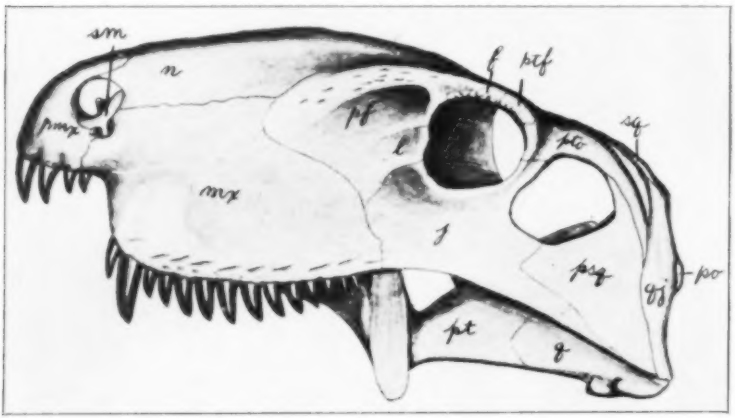

FIG. 2.—Restoration of the left side of the skull of *D. gigas*. *bo*, basi-occipital; *bs*, basi-sphenoid; *f*, frontal; *j*, jugal; *l*, lachrymal; *mx*, maxillary; *n*, nasal; *pmx*, premaxillary; *pv*, prevomer; *pt'*, ascending plate of pterygoid; *pt*, pterygoid; *pf*, prefrontal; *ptf*, postfrontal; *pto*, postorbital; *pa*, parasphenoid; *psq*, prosquamosal; *ps*, ethmoid; *po*, paroccipital (opisthotic); *q*, quadrate; *sq*, squamosal; *st*, stapes.

the squamosal above by the meeting of the quadrato-jugal and parietal; but if these were to separate, and the squamosal and this element came in contact or fuse, we should have the exact condition of the primitive *Rhyncocephalia* (*Saphaeosaurus*), or *Sphenodon*. For this reason I have determined the bone as the prosquamosal. This bone articulates posteriorly with the postorbital, quadrato-jugal, and the lower extermity of the parietal.

The inferior temporal vacuity is formed by the jugal, prosquamosal and postorbital. It is nearly as large as the orbit. The superior temporal vacuity is formed by the postorbital, prosquamosal, quadrato-jugal, and parietal. It is very small, amounting to a small

slit in the *Dimetrodon gigas* No. 1002, and is even doubtfully open in the *Dimetrodon incisivus* (?) No. 1001. The edges of the bones adjacent to the opening are thinned,and in case where the opening is uncertain there is clear evidence of the thinness of the roof of the skull. If this superior temporal opening is just appearing, as seems certain, we have confirmatory proof of the origin of the temporal arches by a process of natural trephining of the completely roofed skull, as proposed by Baur. It is important to notice that the bones

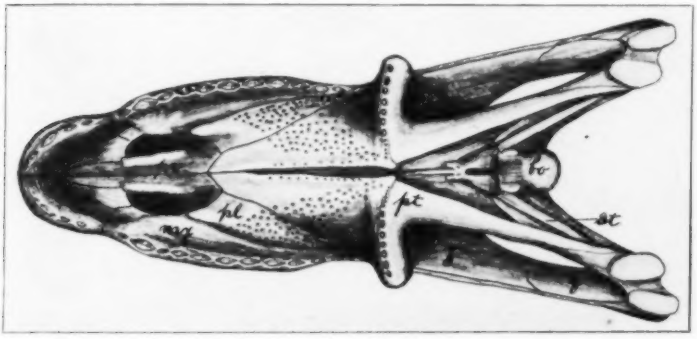

FIG. 3.—Palatal view of the same skull. Letters as in Fig. 2.

have arranged themselves in the position of the perfect arches before the openings appear.

On the posterior face of the skull the remnants of fairly strong stapes was found in position. Unfortunately, neither end was preserved, so that it is impossible to confirm Cope's description of the anterior end of the Pelycosaurian stapes.

On the inferior face of the skull the position of the pterygoids and other bones is confirmed, but the external processes of the pterygoids are shown to have been located farther forward than supposed—at the posterior end of the maxillaries. It is determined that there were no posterior palatine openings between the palatine and maxillary. Anteriorly the nares are separated by the paired prevomers; the sides of the prevomers are marked by rugosities at the inferior opening of the nasal canal.

The ectopterygoid (transverse) is made out for the first time. It is a short bone, articulating with a strong, curved ridge on the inner

side of jugal, which at its lower end becomes sessile, and anteriorly with the maxillary. It covers the anterior and the upper portion of the outer process of the pterygoid.

The bones of the facial region are very similar in position to those of previously described specimens, but there is shown a separate bone at the anterior end of the nasal, forming the posterior wall and a portion of the floor of the external nares. This occupies the same position as the bone called the septo-maxillary in *Sphenodon* by Howes and Swinnerton.[1] The bone has a very peculiar form, being bent at right angles so that the anterior portion forms the posterior half of the floor of the nares, and the posterior half forms the posterior wall. The two bones of the opposite sides meet in the median line, so that they would close the nares; but the inner part of the posterior half is only one-half as high as the outer, so that the inner opening of the nares is elevated. The air entering the nares could not pass directly backward or downward, but first rose over the half partition, and then down into the mouth. The lower edge of the septo-maxillary joins the maxillary and premaxillary. The suture between maxillary and septo-maxillary is marked by two foramina.

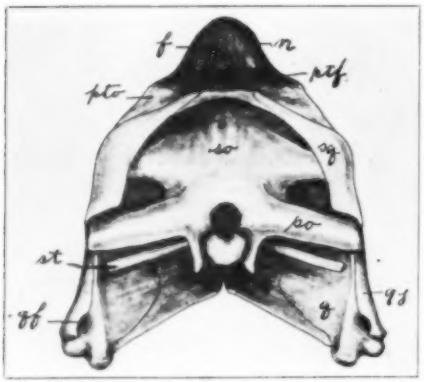

FIG. 4.—Posterior view of same skull. Letters as in Fig. 2.

The section of the skull shows several peculiar conditions. There are paired prevomers which are anteriorly united with the premaxillaries. Passing backward, they are convex upward, so that the anterior portion of the mouth is vaulted. Opposite the maxillary-

[1] G. B. HOWES AND H. H. SWINNERTON, "On the Development of the Skeleton of the Tuatera *Sphenodon* (*Hatteria*) *punctatus*," *Transactions of the Zoölogical Society of London*, Vol. XVI (1903), Part I, No. 1, pp. 1–87, Plates I–VI, Figs. 18.

premaxillary suture the prevomers are free from the side walls of the skull, leaving the elongate openings of the posterior nares. The sides of the posterior nares are marked on the prevomers by ragose ridges. The prevomers are united on the lower surface, but the upper portion is divergent, and receives anteriorly the lower edges of two vertical plates that seemingly originate from the inner edges

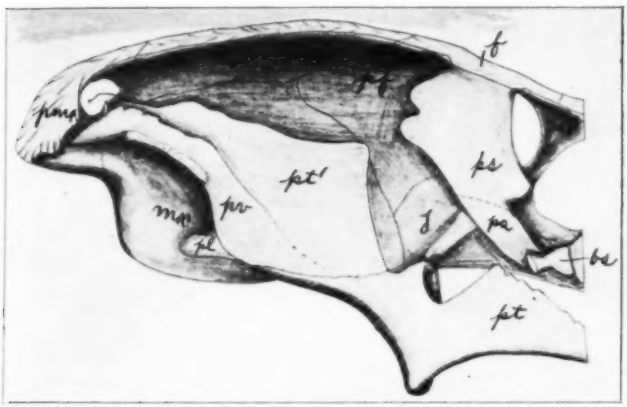

FIG. 5.—Section of the same skull showing septal bones. Letters as in Fig. 2.

of the pterygoids and extend directly upward in the skull. Owing to the somewhat crushed condition of these very slender plates, it is impossible to tell exactly the point of their connection with the prevomers below, but apparently they lie between them, and there was either a squamous contact, or the bones were free in life and have been crushed together in fossilization. The origin of the two vertical plates is somewhat obscure. They occupy the position of vomers behind the prevomers, but the true vomer is a single median bone, and, moreover, is accounted for. Broom[1] has described in *Proterosuchus* two slender vertical plates rising from the inner edges of the pterygoids, with a single median vomer between. It seems that these plates must be the same sort of a structure. They occupy

[1] R. BROOM, "On a New Reptile (*Proterosuchus fergusi*) from the Karoo Beds of Tarkastad, South Africa," *Annals of South African Museum*, Vol. IV (1903), Art. 7.

exactly the same position, but are relatively much larger than figured by Broom.

Posteriorly the parasphenoid is much reduced, and is attached as a slender vertical plate of bone to the anterior end of the basisphenoid between the basiptergoid processes. Above, the parasphenoid articulates directly with a thin vertical plate of bone which expands antero-

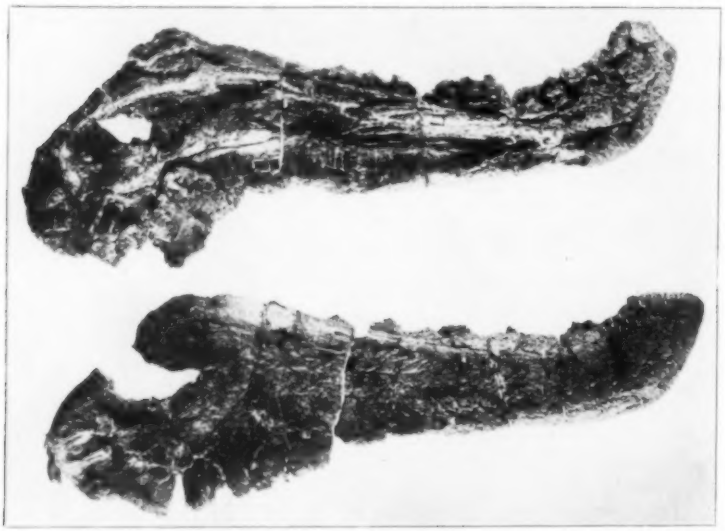

FIG. 6.—Lower jaws of *Dimetrodon incisivus* (?), showing the inner and outer surfaces. Full length of jaws, 33 cm.

posteriorly as it rises in the skull, and finally articulates in the median line with the under side of the frontals. This bone can only be the ossified ethmoid portion of the median cartilaginous septum. The anterior edge of the ethmoid is somewhat irregular and thin, and represents the true vomer; the posterior inferior angle is rounded and thickened and there is an excavation which evidently marks the exit of the 11 nerve from the skull. The presence of a median septum of this character is very peculiar in view of the fact that there are well-developed epipterygoid bones indicated by the preserved lower ends in contact with the posterior portion of the pterygoids.

There was no sign of the lower jaws with the skull of *Dimetrodon gigas*, but with the other skull, No. 1001, the jaws were preserved nearly perfectly. They show that the portion identified by Baur and Case as the articular region of the skull is in reality the articular region of the lower jaw. The articular is small and nearly inclosed by other bones. Its upper face is marked by two deep cotyli, and the posterior edge in specimen No. 1001 has a small hook-shaped projection. The quadrate is supported by the angular, surangular, and splenial (Baur), prearticular (Williston). The posterior ends of these bones stand out from the thin expanded posterior end of the bone, supporting the articular bone on a sort of pedicel instead of on the upper edge of the jaw. This explains why the articular region is so often found isolated in the fossil beds. The posterior portion of the jaw is very thin, but expanded vertically. In both jaws the coronoid bone is lost, but it was a small, thin plate, as shown by the sutures for its attachment. Anteriorly the angular passes far forward, forming the posterior half of the outer side of the jaw. The splenial or prearticular reaches nearly to the middle of the jaw, where it disappears under the splenial (presplenial of Baur). The spenial reaches to the symphasis, but does not take part in it.

As previously described, there are enlarged incisor and canine tusks in the upper jaw, and enlarged incisors in the lower jaw. In *Dimetrodon gigas* the edges of the teeth are crenate, but this and the number of the teeth in the jaws seem to be somewhat variable in the different species of the genus.

In general, the whole skull may be said to bear a remarkable resemblance to the skull of *Sphenodon*, in most parts being directly comparable to it, and varying only in the temporal arches—the ossified interorbital septum, and the vertical plates of the upper side of the pterygoids.

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ON THE STRUCTURE OF THE FORE FOOT OF DIMETRODON.

DURING the summer of 1903, while in charge of the University of Chicago expedition in the Permian fossil fields of Texas, the author collected the right fore leg and foot of a Pelycosaurian reptile of the genus *Dimetrodon*. The species is not determinable at present, but is very close to *Dimetrodon incisivus*, if not that species exactly. When found the bones were badly softened by decay, but after cleaning and hardening I find that those of the carpus, with one exception, are perfectly preserved and in their natural positions. This is particularly fortunate, as it is the exception to find any considerable portion of a skeleton together in the Texas fields.

The author has previously described[1] an imperfect front foot of *Dimetrodon*, No. 114 of the University of Chicago collection, and attempted to place the bones in their natural relations. The present specimen shows that the position of the bones in the figure was erroneous and must be corrected.

Fig. 1 shows the right front foot from the lower surface. The bones added from another specimen are in line only. The specimen has received the number 1003 in the University of Chicago collection of vertebrate fossils.

A study of the specimen brings out first of all the striking resemblance of the foot to the foot of *Sphenodon* (Fig. 2), not only in the number of the bones, but in the arrangement and to some extent the form. This emphasizes the Ryhnchocephalian nature of the Pelycosaurs already demonstrated from the structure of the skull.

The carpus consists of eleven elements. The ulnare is a stout bone with wide proximal end, and resembles the same bone in *Sphenodon* very closely. The radiale is larger than the ulnare, but is not so stout; it is very thin, but elongate and articulates with the distal row of carpals. The intermedium reaches well up between the radius and ulna. There are two centrale. Centrale 1 occupies a central

[1] JOURNAL OF GEOLOGY, Vol. XI, No. 1 (1903), p. 11.

position in the carpus and is much larger than the second. Centrale 2 lies between the ulnare and the third, fourth, and fifth carpals, but is surrounded by bones, as its outer side articulates with the sesamoid. The form and articulation of the five carpals of the distal row are best

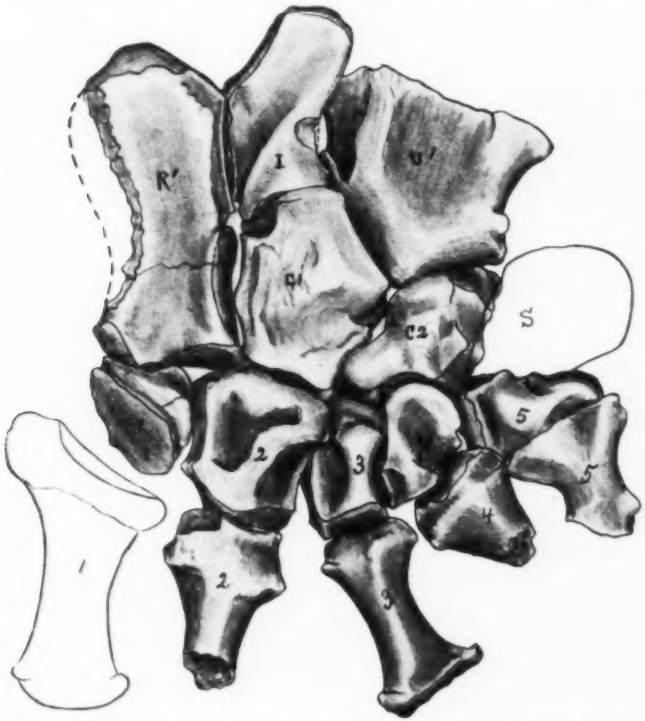

FIG. 1.—Lower side of the manus of the right foot of *Dimetrodon* ×p. *r'*, radiale; *u'*, ulnare; *i*, intermedium; *c* 1, centrale one; *c* 2, centrale two; *s*, sesamoid; 1, 2, 3, 4, 5, carpals and metacarpals. Natural size.

seen from the figure. The fifth carpal is peculiar in its prominent position at the side of the carpus, standing well away from the rest of the bones.

A second specimen of *Dimetrodon* discovered the same summer afforded a nearly complete anterior portion of the skeleton. It has received the number 1001 in the Chicago collection. The bones of

this specimen were somewhat scattered, so that, although the bones of the fore legs and feet were preserved, they were not in position. From the specimen 1003 the bones of the carpus of both sides in specimen 1001 have been placed in position, and both show the presence of an extra element which, from the position of articular surfaces and from comparison with *Sphenodon*, evidently occupies the position of the pisiform bone on the ulnar side of the mammalian carpus. It is a sesamoid bone of considerable size.

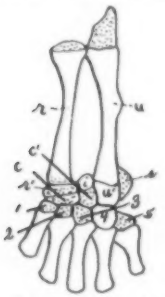

FIG. 2.—Upper side left manus of *Sphenodon* after Bayer and Howse, from Osborn. Lettering as in Fig. 1. Natural size.

The bones of the carpus fit snugly together, with well-developed articular surfaces, making a strong foot. This is also shown by the possession of well-developed phalanges and powerful claws.

The first digit was shorter and stouter than the second. The broad proximal end is characteristic of the first metacarpal. The second digit was probably the largest of the foot, judging from the length of the metacarpal and the imperfect foot of specimen 114. The third and fourth metacarpals are more slender than the second. The fifth metacarpal is a very broad and thin bone articulated to the prominent fifth carpal, so that it stood out from the others at a considerable angle. The articular surface between the fifth carpal and metacarpal is twisted in a peculiar manner, so that it permits of a considerable range of motion. This perhaps explains the fact that the fifth metacarpal and digit were found in the specimen 114 lying at right angles to the fourth. In the description and figure of 114 they were called first and second.

FIG. 3.—Manus of *Procolophon*. From Osborn after Broom. Lettering as in Fig. 1. Natural size.

It is interesting to compare the carpus of *Dimetrodon* with the carpus of *Procolophon* in the light of Broom's determination of the *Rhynchocephalian* nature of *Procolophon*.[1] Fig. 3 is an outline

[1] BROOM, *Records of the Albany Museum*, Vol. I, No. 1 (1903). See also OSBORN, *Memoirs of the American Museum of Natural History*, Vol. I, No. 8 (1903), p. 480.

drawing of Broom's restoration, slightly modified according to Osborn; *i. e.*, the bone marked centrale 2 was called by Broom radiale. It will be seen that the carpus is essentially the same if the radiale is restored. The fifth carpal is missing, but that may well be left open for future evidence, as there is so commonly a fifth carpal in the primitive reptiles.

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ON THE PYROXENITES OF THE GRENVILLE SERIES IN OTTAWA COUNTY, CANADA.

THE pyroxenic rocks associated with the apatite deposits, and by Hunt[1] called pyroxenites, constitute an important feature of the Grenville series over considerable areas north of the Ottawa River in Canada. There has been a wide divergence of views as to their origin, some regarding them as metamorposed sediments, while others consider them to be of igneous origin. The observations of the writer support the latter view. They were made in the vicinity of High Rock, an apatite mine, situated on the right bank of the Du Lièvre River about twenty-one miles above Buckingham and forty miles north of Ottawa. The openings here cover about six hundred acres in all on the tops of the hills which rise to a height of seven hundred feet above the level of the river. The longer axes of the hills trend south 40° east parallel with the strike of the rocks of the region. The apatite occurs in veins or pockets in the pyroxenite or along the contact of the pyroxenite with dikes of syenite which cut it in various directions. As described by the writer,[2] this dike rock varies from a course-grained syenite to a rather fine-grained gneiss. As an intermediate stage there occurs at a number of places, both on the surface and associated with the apatite in the diggings, a peculiar spheroidal phase of the syenite, called "leopard rock," which is considered due to dynamic processes.

The pyroxenites usually occur in parallel bands intercalated in the quartzites, though they sometimes cut across the bedding of the latter. Fig. 2 represents the relations of these rocks as seen at one locality on the hill. The pyroxenite bands, which have the appearance of an intrusion in the quartzite, have suffered breaking and stretching, while quartzitic material has taken possession of the spaces between the disrupted blocks. Still better are these relations shown in Fig. 3. At this locality the pyroxenite appears in the main to have

[1] *Geology of Canada*, 1866, p. 185; *Chemical and Geological Essays*, p. 208.

[2] *Bulletin of the Geological Society of America*, Vol. VII, pp. 95–134.

followed the bedding of the quartzite, but in places it has broken across it and has involved considerable portions of the quartzite within itself. The rocks strike south 40° east and are cut by joints

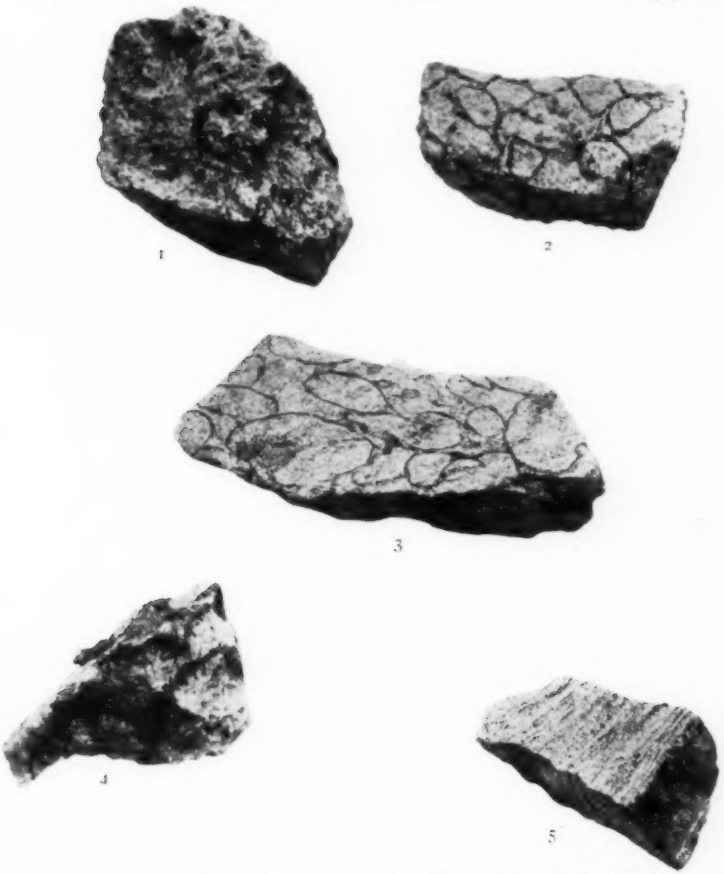

FIG. 1.—Syenite Gneiss from dikes cutting the pyroxenite at High Rock mine, Ottawa county, Canada. (1) Shows the coarse-grained phase of the Syenite, (2), (3), and (4) represent the Leopard Rock phases, and (5) the gneissic phase.

having a general direction of north 70° west. As shown at the upper left corner of the cut, the jointing is more pronounced in places along the contact with the pyroxenite. Both rocks are cut by small dikes

or stringers one-half to one inch in width, one (*a*) consisting of basic (probably hornblendic), and the other (*b*) of feldspathic material. In places masses of the pyroxenite appear as inclusions in the syenite dikes, and without close examination might easily be taken for a segregation of basic material in the syenite.

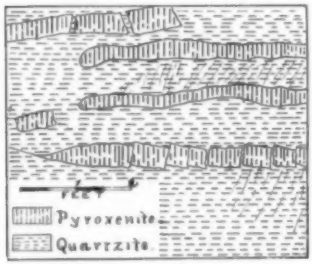

FIG. 2.—Showing pyroxenite intercalated in the quartzite.

Under the microscope the pyroxenite is shown to consist chiefly of a pale, almost colorless monoclinic pyroxene, apparently augite. It is for the most part coarsely crystallized and has a pronounced prismatic cleavage. Polysynthetic twinning in thin lamellæ parallel to the orthopinacoid (100) is frequent, giving a pronounced diallage-like appearance, probably due to the development of gliding planes as a pressure phenomenon.[1]

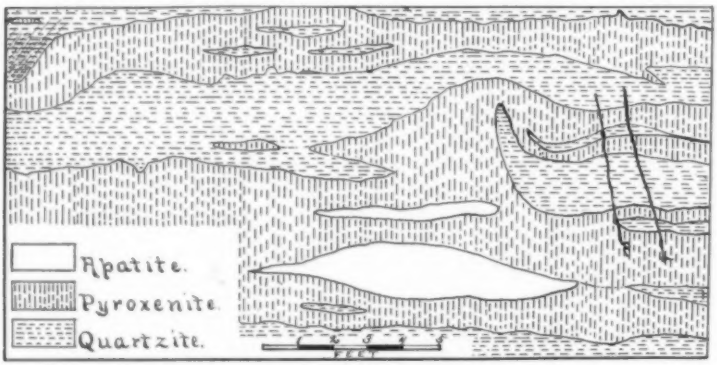

FIG. 3.—Showing the pyroxenite interbedded with the quartzite and including portions of the latter.

Further evidence of dynamic movement appears in the slight lack of correspondence in the continuation of cleavage cracks, in the bending and fracturing of lamellæ, and especially in the extinction shad-

[1] F. ZIRKEL, *Lehrbuch der Petrographie*, Vol. I, p. 612.

ows, though the last are more easily distinguished in the larger grains. The lamellæ are usually thin, varying from extreme fineness to 0.013 mm in thickness. In sections parallel to the clinopinacoid (010) the extinction angles of the lamellæ measured from 38° to 43°, and none were found to extinguish parallel, thus precluding the possibility of an intergrowth of augite and hypersthene. (Fig. 4.)

FIG. 4.—Section of pyroxenite. *A*, augite; *Ap*, apatite inclosing small prisms of zircon; *S*, scapolite; *T*, titanite.

Along with the augite there occur as minor constituents in varying, usually small, proportions, scapolite, quartz, apatite, brown mica, hornblende, and an opaque iron ore.

The scapolite has a cloudy, yellowish-gray, fibrous appearance usually, and in places occurs in considerable amount in graphic intergrowth with the augite. This is especially the case near the contact of the pyroxenite with the syenite-gneiss. An analysis of the scapolite by William Hoskins gave the following results:

SiO_2	50.230
Al_2O_3	27.207
FeO	11.123
CaO	8.175
MgO	1.732
	98.464

This indicates a high percentage of iron, with a correspondingly low showing of lime, possibly attributable to the altered condition of the material.

Apatite appears in considerable amount as irregular grains and aggregates. In some cases the pyroxenite and apatite are found in

alternating parallel lamellæ resembling eozoon and sometimes mistaken for it.

The mica is usually confined to the portions showing a laminated structure where it occurs in considerable amount along certain planes.

Titanite occurs in occasional grains, showing the usual chocolate brown color and well-marked development of gliding planes parallel to (221) characteristic of American sphenes.[1]

The hornblende which is small in amount is compact and strongly pleochroic. It is usually in close connection with the augite, and the relations of the prismatic cleavages are sometimes such as to indicate that the ortho- and clino-pinacoids of the two minerals lie parallel.

ORIGIN OF THE CANADIAN PYROXENITES.

Various opinions have been expressed as to the origin of the Canadian pyroxenic rocks. Much has been written concerning the origin of the apatite deposits which occur in them, but it is manifest that any conclusion regarding these would be shaped, in part at least, by the view held concerning the origin of the pyroxenites themselves. The occurrence of the pyroxenites in bands alternating with the quartzites and gneisses simulating bedding has led some writers to regard them as of sedimentary origin. When first used by Dr. Hunt, the term "pyroxenite" was applied both to rocks which have been recognized as intrusive, like those of Rougemont and Montarville, and to the more or less massive beds or nests of pyroxene so often intercalated in the so-called Archean limestones of New York and Canada.[2]

Concerning the latter, Hunt states that they grade, on the one hand, into granitoid orthoclase gneiss and, on the other, into limestone, and concludes that "these peculiar strata, which contain at the same time the minerals of the associated gneiss and of the limestone, may be looked upon as beds of passage between the two rocks."[3] They were regarded by this author[4] as having been deposited originally

[1] G. H. WILLIAMS, *American Journal of Science*, Series III, Vol. XXIX, p. 486.

[2] G. H. WILLIAMS, *American Geologist*, Vol. VI (1890), p. 45.

[3] T. J. HUNT, *Geology of Canada*, 1866, p. 185.

[4] *Chemical and Geological Essays*, 1891, p. 305.

as amorphous chemical sediments, which under moderate heat and pressure arranged themselves and crystallized, generating the various mineral species by a change which Gümbel designates *diagenesis*. The apatite deposits were regarded by Hunt[1] as vein formations resulting from hot-water solutions, though some were thought to occur in beds. The belief as to the vein origin of these deposits was based on the following considerations: (1) the rounded form of the apatite crystals, which he considered due to partial solution after deposition, rather than to fusion in a molten magna; (2) the manner in which one mineral incloses another, as in the case of crystalline calcite, rounded into pebbles and inclosed in the center of apatite crystals; (3) the banded structure observed in some deposits; (4) drusy cavities. The banded arrangement is not a frequent characteristic of the deposits, but is sometimes seen. Dawson considers many of the Ontario deposits as true beds and of organic origin, thus apparently postulating a sedimentary origin for the inclosing rocks,[2] though not necessarily for all of them.

Harrington, in his admirable report on the apatite-bearing veins of Ottawa county, takes the same view as to the origin of the pyroxenites, and contends that the conclusions of Brögger and Reusch concerning the eruptive origin of the apatites of Norway do not apply to the Canadian occurrences. He adds:

> The pyroxenites often contain disseminated grains of apatite, and no doubt they are the strata from which the apatite of the veins has been chiefly derived. If, as has been suggested, the apatite of these ancient strata represents material accumulated by organic agencies, then the connection of the pyroxene and apatite may be that the former constituted an ocean bottom particularly suitable for the life of the creatures which secreted the phosphatic matter.

W. Boyd Dawkins,[3] who visited this locality in 1884, adopts Harrington's conclusions, though he adds: "Were it not that it is bedded, it would pass muster as an eruptive rock." He concludes that the apatite deposits were formed in fissures in the Archean gneisses by hydrothermal or aquo-igneous action under conditions

[1] *Geology of Canada*, 1863 pp. 477, 644; *American Journal of Science*, 2d ser., Vol. XXXVII, p. 252; *Chemical and Geological Essays*, p. 208.

[2] Sir J. W. Dawson, *Quarterly Journal of the Geological Society*, Vol. XXXII (1876), p. 289.

[3] *Proceedings of the Manchester Geological Society*, December 2, 1884.

of heat and pressure of the same general sort as that by which the rocks themselves have been affected.

On the other hand, the eruptive origin of these rocks has been upheld by various writers. In 1884, in his report on the apatite deposits, Torrence[1] guardedly states that these rocks may be due to contemporaneous intrusion. The apatite is regarded as due entirely to segregation from the pyroxene rock and never of a bedded character. In 1884 Coste[2] contends strongly for the eruptive origin of the pyroxenite, while the apatite is looked upon as possibly due to emanations accompanying or immediately following the intrusion of the igneous mass.

Dr. Selwyn subsequently supported this view, and said: "They are clearly connected for the most part with the basic eruptions of Archean date."

R. W. Ells[3] holds that, contrary to the observations of earlier writers, the pyroxene rock is not interstratified with the gneisses and quartzites, but occurs in dike-like masses and bands, which sometimes cut across the regular stratification of the associated rocks, and at other times traverse these along the bedding planes for some distance, and then abruptly change their course after the manner of other intrusives. In places, a gneissic structure is observed, but this, as in the case of the syenite, is doubtless due to great pressure. The author concludes that the apatite may be due to vapors charged with phosphoric and fluoric acids ascending along the sides of the dike.

The igneous origin of these pyroxenic rocks seems to be abundantly confirmed by their mode of occurrence at High Rock, as herein shown, and at numerous other places within the apatite district. While in general the pyroxenites extend along the bedding plane of the quartzites, they sometimes cut across the strike of these rocks after the manner of intrusions, as stated by Dr. Ells. In some places isolated lenticular masses of these rocks or a similar hornblende rock appear along the bedding plane of the quartzite, which are inexplicable except on the theory that they represent cross-

[1] *Geological Survey of Canada, Report of Progress*, 1882–83–84, Report J.

[2] *Ibid.*, 1887–88, Report S, p. 64.

[3] *Canadian Record of Science*, January, 1895.

sections of small offshoots from the main mass which have thrust themselves in between the beds of quartzite and were subsequently exposed by the planing down of the surface. Ells cites a number of cases where the pyroxenite cuts the stratified gneiss. At Little Rapids mine on Lièvre River the pyroxene dike is said to cut the banded gneiss at an angle of 30° or more. At North Star mine the

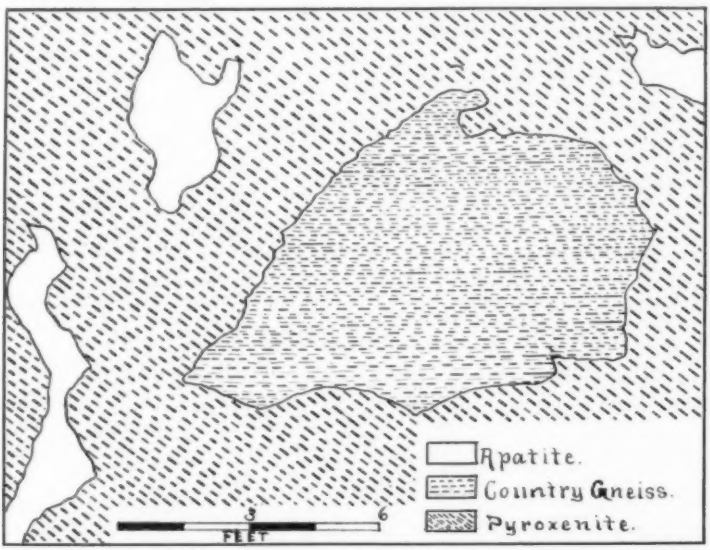

FIG. 5.—Bowlder of country rock imbedded in pyroxenite, High Rock mine, Ottawa county, Canada. (After Penrose.)

gneiss has been heaved up and bent around a portion of the dike, the contact of the two being sharply defined. A similar occurrence has been figured by Professor Penrose.[1]

That the pyroxenite should so often occur in sheets alternating with the quartzite is not strange, considering the extent of disturbance which these appear to have suffered and the more favorable conditions afforded by the bedding planes for the passage of the lava.

Further, and it would appear conclusive, evidence of the erup-

[1] R. A. F. PENROSE, "Nature and Origin of Deposits of Phosphate of Lime," *U. S. Geological Survey, Bulletin No. 46*, p. 25.

tive character of the rocks is found in the inclosures of country rock sometimes observed in them (Figs. 2 and 3). An occurrence of this kind at High Rock is noted in the above-cited report by Professor Penrose whose figure is here reproduced.

The evidence, therefore, clearly warrants the conclusion that the pyroxenic rock is intrusive. And that it represents the oldest intrusive is shown by the manner in which it is cut by the later intrusions of syenite and diorite, or so-called "trap."

NOMENCLATURE.

As heretofore stated, the term "pyroxenite" was first used by Dr. Hunt for an intrusive rock composed mostly of pyroxene with magnetite and ilmenite from Mount Royal and other places in Canada.[1] Later[2] he applied the name to the pyroxenic member intercalated in the limestones and quartzites of the apatite district, a rock generally regarded as having no genetic relationship with the first. Among the Canadian geologists it has come to be applied almost exclusively to the latter rock. Lacroix uses the term *gneiss à pyroxène et à wernerite* for a rock of essentially the same character from Brittany.[3] In the later work[4] Lacroix conforms to the German and English usage of calling this rock an "augite gneiss." These gneisses are said to occur in the upper part of the gneiss system, and are usually characterized by scapolite in greater or less abundance as in the Canadian rocks. The term "pyroxenite," which had previously been applied to these occurrences, is reserved by this author for rocks composed exclusively of pyroxene.

In 1890 G. H. Williams[5] used Hunt's term in its original signification for basic intrusions occurring in the eastern portion of the Piedmont Plateau in Maryland. These rocks are of a somewhat different type from the Canadian rocks, in that they are composed chiefly of an orthorhombic instead of a monoclinic pyroxene. Williams speaks approvingly of Lacroix's substitution of the term

[1] *Geology of Canada*, 1863, p. 667.

[2] *Catalogue of Canadian Rocks at Paris Exposition*, 1862; *Geology of Canada*, 1863–66, pp. 185–226.

[3] *Bulletin de la Société française de Mineralogie*, Vol. X (1887), p. 288.

[4] *Ibid.*, Vol. XII (1889), p. 83.

[5] *American Geologist*, Vol. VI (1890), p. 35.

"pyroxene-gneiss" for the French equivalents of the pyroxenic rocks occurring in beds or nests in the Grenville series, and contends that the Canadian use of the term "pyroxenite" for these rocks should be abandoned and the name restricted to non-feldspathic plutonic rocks free from olivine. The term is thus made a class designation co-ordinate with "peridotite," given by Rosenbusch to the corresponding olivine-bearing series, and the author says that its use as a designation for any rocks except those of igneous origin should be abandoned. As nearly all the Canadian pyroxenites were regarded by Williams, evidently on the authority of Hunt and others, as metamorphosed sedimentaries, they were excluded from the list. Zirkel[1] adopts Williams' classification, and includes these rocks with Lacroix's wernerite rocks under the pyroxene gneisses of the crystalline schists, apparently, though without distinct reference.

Pyroxenic rocks with augite as the chief basic mineral are not of common occurrence. Clements has described one from Alabama[2] which seems to be closely allied to these Canadian pyroxenites. In a comparison of the Ottawa pyroxenites with younger rocks, manifestly consideration must be given to the long period of time during which the former have been subjected to mountain-making forces.

As the result of this study we conclude:

1. That these pyroxenic rocks of Ottawa county were intruded into the overlying sedimentary beds at considerable depths, and solidified originally as a coarse-grained pyroxenite consisting chiefly of augite, but approaching the gabbro end of the series.

2. That, through the changes effected by pressure and metasomatic processes, whereby original structures have in large part disappeared, the rock should now be classed with the pyroxenite-gneisses.

3. That the apatite deposits associated with these rocks were due to fumarolic action at the time of the intrusion of the pyroxenites, and also, to a greater extent possibly, to that attending the later intrusions of syenite.

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[1] *Lehrbuch der Petrographie*, Vol. III, p. 149.

[2] *Bulletin 5*, Geological Survey of Alabama, p. 163.

A TYPICAL CASE OF STREAM-CAPTURE IN MICHIGAN.[1]

THE geographic relations of the phenomena to be described herein are shown in the accompanying map (Fig. 1). The wider relations are shown in the smaller map, the particular location being near Rawsonville, east of Ypsilanti, Mich.; while the more special relations are shown in the larger map.

The least modified and most typical remnant of the captured valley to be described is shown in Fig. 2—a view taken from the point *A* on the larger map, and embracing the upper part of what is now the Oak Run valley. The valley seen in the foreground has a typical trough-like configuration, with very definite slopes which make a distinct angle of 20° with the flat and marshy valley floor. No stream, however, flows through this portion. In the middle distance the valley floor terminates abruptly on the side of a deeper valley. The termination is given artificial distinctness by a roadway crossing at this point which has been raised about three feet on account of the marshiness of the valley floor. Nearly opposite this abrupt end of Oak Run valley, another valley, Oak Ravine, comes in obliquely from the right, as partially shown by the snow-covered slope near the group of elms in the middle of the picture. This valley heads in a clump of oaks, the tops of which are visible in the right background. The drainage of the valley is discharged opposite the truncated head of Oak Run valley. At the point of their nearest approach, in the left center of the view (Fig. 2), Oak Run and Oak Ravine are intercepted by an embayment of the Huron River flood-plain, whose bluffs are here about forty-five feet high. This embayment was made by a meander of the Huron River which cut back into the drift-plain of the region about a quarter of a mile, and reached the line of the two valleys in question (see map, Fig. 1). This drift plain constitutes the horizon in Fig. 2, and the bluff of the embayment is partially shown at the left below the barn.

[1] I am greatly indebted to Professor M. S. W. Jefferson for the accompanying photographs and for helpful suggestions in the preparation of this paper.

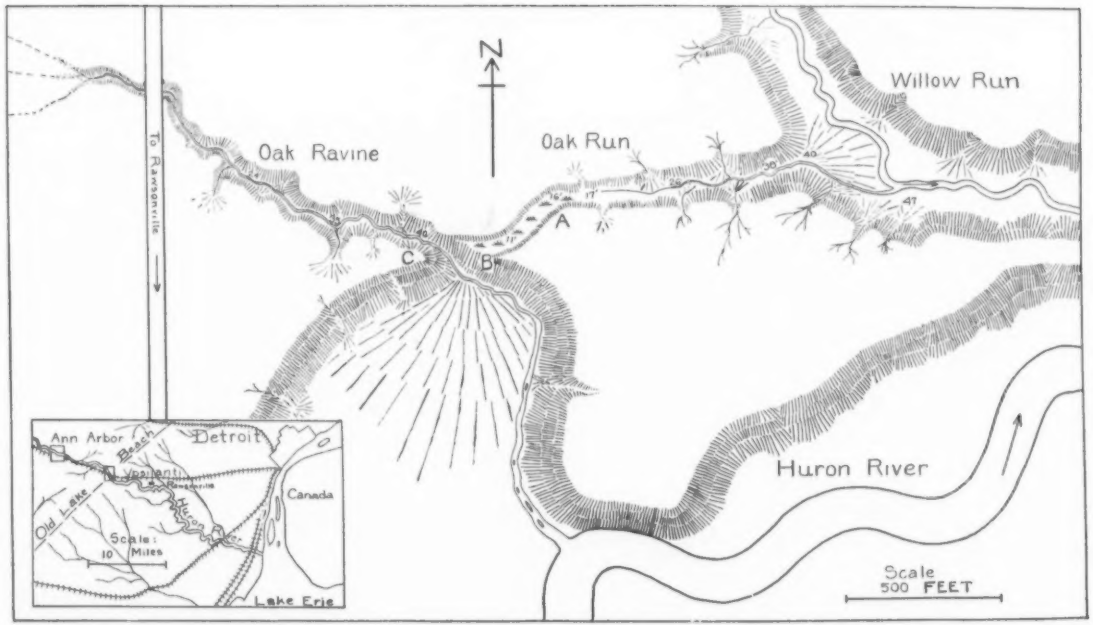

FIG. 1.—Map of Beheaded Oak Run.

When the encroachment of the bend of the Huron River began, Oak Ravine constituted the upper part, and Oak Run the lower part of a single valley, discharging into Willow Run; but when the right bank of their common valley had been broken down by the attack of the Huron, the waters of the headward portion were diverted and cascaded down the bluff of the embayment to the Huron below, while

FIG. 2.—Oak Run Valley where headwaters are taken out to left.

the part of the channel seen in the foreground of Fig. 2 was left a marshy flat. At the present time these two valleys, once continuous, have a difference of elevation of thirty feet, due to the erosion of the bottom of the upper section, while the head of the lower section has not been appreciably lowered.

The drainage area of the lower section, now the valley of Oak Run, is very small, probably less than 100 acres. The drainage area of the diverted upper section is several hundred acres. The difference in the erosion since the disseverance of the valley has brought the configuration of the two portions into sharp contrast. That of the lower portion at its head, where erosion has practically

stopped, has already been noted. That of the upper section, near its mouth, is shown in Fig. 3—a view taken from the point *B* on the map (Fig. 1) and looking westward up the valley.

The captured upper portion of Oak Ravine.—It will be noted that

FIG. 3.—Oak Ravine—the deepened headwater valley of Oak Run.

this upper portion has the sharp characteristics of youth. The side slopes have angles as high as 25°. The stream in the bottom of the valley has no flood-plain, but hurries over rapids and little falls, giving evidence of decided youthfulness. Although pushed slightly to one side or the other by the alluvial fans built forward from the mouths of tributary gullies, it is in the main entirely competent to care for the waste creeping into it. The depth of the ravine below the upland is shown on the map at intervals of 250 feet by the numbers in the bottom of the ravine. It is seen from these numbers that

the profile of the descent is a normal curve, the flattest part being near the mouth and the steepest near the head of the ravine.

Out on the alluvial fan at the mouth of the ravine the stream finds a much gentler descent than it has previously enjoyed, and so begins to build up its bed, little sand-bars and islands showing the overloaded condition of the stream.

The heads of the tributary gullies have a characteristic amphitheatral shape. The slopes all lead to one central point from which the drainage follows a main course to the mouth of the gully. The waste slopes exhibit at present but moderate activity, although six or eight trees, prostrate because of undercutting, bear witness to the steady deepening of the ravine.

The beheaded valley, Oak Run.—The widths of the flat valley floor of Oak Run valley, expressed in feet, at intervals of 200 feet from the head, are as follows: 26, 22, 17, 16, 15, 10, 0. At the next to the last point given, Oak Run begins as a definite stream, and the valley floor gradually disappears, the valley becoming *V*-shaped, so that, standing at the mouth of Oak Run and looking upstream, one has a view similar to that shown in Fig. 3, and the stream here exhibits the same competency to remove waste, although no prostrate trees speak of great activity. On the map the numbers in the valley of Oak Run speak of abnormal valley descent, the flattest portion of the floored part of the valley being near the head. The steepening of the course continues until halfway down Oak Run, where the normal curve is assumed and maintained for the rest of the way.

The tributary gullies in the upper part of the valley have the same amphitheatral shape as those of Oak Ravine display, but farther downstream the dendritic pattern is assumed. The gullies have here gashed the upland deeply, and tons of earth are carried down them every year. Those at the head of the valley are long and gently sloping, and are gradually building up the valley floor. Those farther down push the weak stream from side to side until its increased volume enables it to pursue a more independent course. The greater part of the old watershed of Oak Run now drains into Oak Ravine, so that immediately after capture had taken place the now greatly diminished Oak Run began aggrading its valley-floor until the grade attained by the stream enabled it to carry all of the waste brought

in by tributaries and washed down from the valley sides. A part of the flat valley floor is thus accounted for; that near the head being explained by the fact that there is here no surface stream at all, but little waste has been removed, and the filling of the valley continues without interruption.

One of the clearest evidences of capture is the remnant of Oak Run valley perched on the Huron bluff and running neatly around

FIG 4.—Looking down Oak Run from across mouth of Oak Ravine.

a spur into Oak Ravine. The bench-like effect which it gives to the bluff is very clearly seen in the field, although it appears but faintly in Fig. 2 because of the distance at which the view was taken. The bluff at the elbow of capture is covered over with tufts of grass and peat sliding down from the channel of Oak Run. Wet-weather gullies are eating farther and farther back, so that the bench will finally disappear. These facts unite with other evidence presented in indicating the extreme recency of the capture.

The whole case is so complete in detail and so small in size that it furnishes at once a perfect example of this kind of stream-adjustment

and an excellent pocket specimen, as it were, for classes in field geography. Since the discovery of this example of stream-capture, a study of the map reveals evidences of other cases near Ypsilanti which will be studied in the field during the spring and summer.

Relation to examples previously discussed.—The seizure of drainage areas of weak streams by more powerful adjacent streams forms an interesting phase in physiography. Broadly speaking, two forms of stream-capture may be recognized. The one takes place gradually through the headward growing of streams flowing down the steep inface of a cuesta, the captured stream originally flowing down the gentler outface. Gilbert describes such cases in his *The Geology of the Henry Mountains*, and Heim long ago pointed out the capture of the Inn by the steep-sloping Maira. To this class belong also cases later described by Professor Davis: the capture of the upper Schmiecha by the Eilach in the Swabian Alps, piratical Deer Run in eastern Pennsylvania, and a number of cases along the Blue Ridge of Tennessee.

Kaaterskill sheet, New York, of the U. S. Geological Survey, topographic sheets, shows Plaaterskill Creek undercutting the drainage areas of a southern tributary of Scoharie Creek; while a northern tributary is being undercut by the Kaaterskill. Both the Plaaterskill and Kaaterskill run directly into the Hudson, making a descent of about 900 feet in the first few miles of their course. Scoharie Creek drains northward into the Mohawk, and so finally into the Hudson, and must descend but 900 feet in at least fifty miles. It is therefore losing territory to the more vigorous streams gnawing into the eastern border of the upland.

The river systems of the Atlantic coast owe their present extension to westward cutting. One by one the streams of the Appalachian region have been diverted to the Atlantic, until but a single river continues its original course to the Mississippi. This is the Kanawha, wearing in canyon form the marks of its long struggle against the diverting tendency.

The second form of capture is accomplished by the sideways swinging of a master-stream, which may thus eventually eat into the side of a neighboring stream or behead one of its own tributaries. It may have been in this manner that the Red River came to enter the

Mississippi at Turnbull's Island, as shown on the eight-sheet map of the alluvial valley of the Mississippi. The Red may have run right to the Gulf at one time until the meandering Mississippi bit into the valley and carried off the waters. In time of drought, the Red discharges into the Mississippi, but in flood season it discharges partly into the Atchafalaya which runs into the Gulf. Bayous at Turnbull's Island indicate a possible westward meandering in the Mississippi sufficient to produce such a result. In the same way Bayou Maçon appears to have once discharged into the Tensas, and so into the Red, while Lake Maçon would seem to indicate that the Mississippi had cut into the river and captured it at that place. Eastward cutting in the Mississippi may then have carried the river away from Bayou Maçon, so that that stream now discharges through its old channel. Were it not for the extreme flatness of the Mississippi flood-plain, these streams would probably have continued to run into the Mississippi even after its withdrawal from the scene of capture. The silting up of the ends of the cut-offs seems on that faint grade to have been sufficient to return the streams to their old courses.

An example of capture from neighboring streams is that of the capture of the upper waters of Beaverdam Creek by the Shenandoah at Snickers Gap, as described by Bailey Willis; or the well-known capture of the upper Chattahoochee by the Savannah on the boundary between Georgia and South Carolina.

In the *National Geographic Magazine*, June, 1896, p. 189, in an article entitled "The Seine, the Meuse, and the Moselle," Professor Davis describes the capture of the Ste. Austreberte by the Seine, which, swinging past Quévillon and St. Martin, cuts into the bluffs bordering the upland at Duclair. The Ste. Austreberte is diverted from its previous course across the spur marked by the Forêt de Jumièges. The same writer describes a similar case on the Marne.

The Huron River exhibits the latter type of capture. During its youth it maintained a course, across what had been but recently the floor of a glacial-marginal lake, with strict propriety. Its tributaries flowed to the southeastward for the same reason as did the master-stream, and entered the Huron at a slight angle. The moment that the powerful Huron began swinging from side to side,

the integrity of the little streams adjacent to it began to be endangered. It must eventually happen that capture would become more and more imminent, or perhaps actually be accomplished. In this manner the Huron cut its way into the valley of Oak Run and beheaded it, being helped the sooner to this climax by a turn in Oak Run just opposite the point where the Huron has meandered so strongly.

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THE DEPOSITION OF THE CARBONIFEROUS FORMATIONS OF THE NORTH SLOPE OF THE OZARK UPLIFT.[1]

INTRODUCTION.

THE following study is the outgrowth of field-work performed by A. F. Smith[2] and the writer in the spring of 1902 for the Missouri Bureau of Mines and Geology. Miller county was carefully mapped,

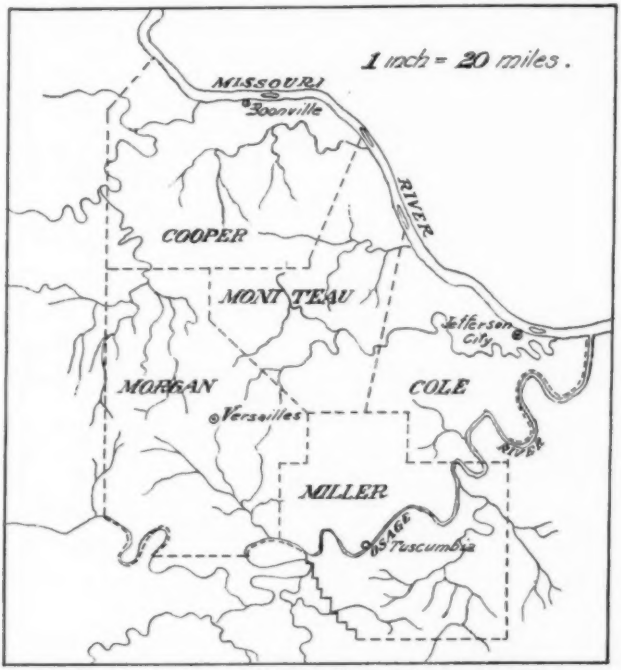

FIG. 1.—Sketch map of North Slope of the Ozark Uplift.

while Morgan, Moniteau, Cole, and Cooper counties were visited. These counties form the center of the north slope of the Ozarks. (See Fig. 1.)

[1] Published by permission of the Director of the Missouri Bureau of Mines and Geology.

[2] Acknowledgments are due A. F. Smith for valuable suggestions.

TOPOGRAPHY.

The northern flank of the Ozark uplift is a plain sloping gently to the north. Its level surface is due to Tertiary peneplanation.[1] In the vicinity of the major streams the plain is intimately dissected and the topography is mature.

STRATIGRAPHY.

The stratigraphy is summarized in the following table:

Recent.	Osage alluvium.	
Pleistocene.	Glacial bowlders in Osage alluvium.	
	Unconformity.	
Pennsylvanian	Graydon sandstone. Massive, medium-grained sandstone, more or less conglomeratic. Lithologically scarcely to be distinguished from the Pacific sandstone. 0–75 feet thick.	
	Coal-Measure shale. Shale, more or less conglomeratic, bituminous and cannel coal and limestone. 0–156 feet thick.	
	Saline Creek cave-conglomerate. Unassorted conglomerate composed of arenaceous or calcareous shale containing pebbles and blocks of older formations. Grades into Coal-Measure shale. 0–60 feet thick.	
	Unconformity.	
Mississippian	Burlington limestone. White, coarse-grained, fossiliferous limestone. 0–108 feet thick.	
	Chouteau limestone. Buff, argillaceous limestone. 0–85 feet thick.	
	Unconformity.	
Undifferentiated Cambro-Ordovician	Pacific sandstone.	Dolomites, sandstones, and shales. Referred to below as "Cambro-Silurian."
	Jefferson City formation.	
	St. Elizabeth formation.	
	Gasconade limestone.	
	Gunter sandstone.	
	Unconformity.	
Probable Cambrian	Proctor limestone.	

It is the purpose here to describe the sequence of events connected with the deposition of the Carboniferous, and particularly the Pennsylvanian, formations, rather than the detailed stratigraphy.[2]

[1] MARBUT, *Missouri Geological Survey*, Vol. X, p. 27.

[2] For stratigraphy see BALL AND SMITH, "The Geology of Miller Co.," *Missouri Geological Survey*, 2d ser., Vol. I, pp. 23–122.

THE DEPOSITION OF THE CARBONIFEROUS FORMATIONS.

The Chouteau and Burlington.—The Chouteau and the Burlington limestones lie unconformably upon the Cambro-Silurian dolomites, the Burlington apparently overlapping the Chouteau. The pre-Burlington land surface was of the same order of ruggedness as the present, and the sea advanced over the land too rapidly to cut it into a submarine plain. North of the Osage River Burlington outliers occur both on the hilltops and in the valley below. South of the Osage the present land surface is lower than the Burlington sea bottom, and only residual Burlington bowlders are now found there. Since this old topography was not base-leveled, several uplifts may have occurred between the Trenton and Burlington.

Residual Burlington chert indicates that the early Carboniferous sea covered all Missouri but the country surrounding the St. Francois Mountains. If land existed around them, it must have been incapable of furnishing large amounts of clastic material to the sea. Fossils show that the sea was teeming with animals too fragile to resist heavy waves, but requiring gentle currents to furnish food material.

The interval between the Burlington and Coal-Measure deposition.—Elevation, with contemporaneous erosion, produced, by the time of deposition of the Coal-Measure rocks, a topography similar in ruggedness to the present topography. The thickness of the Burlington limestone appears to have varied from 40 to 180 feet.

At the beginning of the elevation the rivers had renewed strength, but until the Burlington limestone, which is lacking in clastic grains, was cut through, erosive tools were doubtless lacking. Still solution occurred on a large scale, as shown by the deposition of the Saline Creek cave-conglomerate and the Coal-Measure shale in joints, enlarged by solution, in sinks and in caves. The inter-Carboniferous conditions were doubtless somewhat akin to those now existing in limestone regions in the tropics, in which we know caves and sinks to be very abundant. The extent to which observation shows solution occurred warrants a somewhat full discussion of the principles of solution.

The conditions favoring solution[1] are:

[1] The rest of this section is the application to a particular area of principles set forth in VAN HISE'S forthcoming treatise on *Metamorphism*.

1. *High carbon-dioxide content.*—The limestone deposition of the Mississippian period, as Chamberlin has shown, set free a large amount of carbon dioxide. This carbon dioxide acted as a blanket to keep in the sun's heat, and greatly increased the power of water to dissolve limestone.

2. *High barometric pressure.*—Carbon dioxide being over one and one-half times as heavy as air, its presence would increase the barometric pressure, thus proportionately increasing the chemical activity of gases and liquids.

3. *High and constant temperature.*—In post-Burlington times the Ozark region was an island about 160–200 miles in diameter. Because of its insular position and the high carbon-dioxide content in the atmosphere, the climate must have been humid, equable, and warm. The plants of the Coal-Measure shale indicate a tropical or subtropical climate. The chemical activity of water at 0° C. is almost nil, but with increase in temperature the solvent power increases out of all proportion to the thermal rise. Since seasonal changes were doubtless slight, solution could work the year around.

4. *High humidity.*—The seas surrounding the Ozark island would furnish abundant moisture both to abstract the carbon dioxide from the air and to bear it through the rocks.

5. *Soluble material to act on.*—The purity of Burlington limestone and the porosity of the Cambro-Silurian dolomites render each easily soluble, and caves, sinks, and natural bridges are common in the Ozark region today. As the Burlington limestone is coarse and the Cambro-Silurian dolomites medium-grained, the relative solubility of the latter would be increased. As an illustration of this the crinoids, the largest calcite grains in the Burlington limestone, are the last to be silicified in the metamorphism to chert.

6. *Moderate topographic relief.*—Moderate topographic relief furnishes conditions favorable to slow percolation and unfavorable to excessive mechanical erosion. The presence of post-Burlington sink-holes on the upland and in the adjacent valleys indicates that the level of post-Burlington ground water, and in consequence the topography, was broadly similar to that of the present day.

7. *Thick mantle rock.*—Thick mantle rock tends to retard runoff and to increase the time in which solvent waters may act. Solu-

tion doubtless formed a deep residual soil, partially from the insoluble residue of the Burlington limestone, but largely from that of the Cambro-Silurian dolomites and sandstones.

8. *Abundant plant and animal life.*—Plants and animals are important, in producing, directly or indirectly, carbon dioxide. The tropical or subtropical climate, the humidity, and the abundant carbon dioxide favored abundant plant life.

The chief underground circulation must have been to the north and northwest to the Coal-Measure sea, following the present and doubtless the former dip of the strata. Judging from the pre-Coal-Measure sink-holes, the water level must have been from 40 to 125 feet below the pre-Coal-Measure surface. The surface circulation was probably bounded below by the intercalated shales of the Cambro-Silurian formations. At the beginning of pre-Coal-Measure erosion the surface circulation may have been but 150–250 feet deep.

Because of the ready solubility of the Burlington limestone and, perhaps, of initial depressions in the upper surface of this formation along pre-Burlington drainage lines, arising from the unequal thickness of the Burlington cover, erosion tended to exhume the old valleys. They may be referred to as "resurrected valleys"—a term kindred to "resurrected mountains" (Davis).

Deposition of the Saline Creek cave-conglomerate.—The oldest formation of the Pennsylvanian, the Saline Creek cave-conglomerate, lies in joints, enlarged by solution, in sink-holes, and in cave-galleries in the Burlington and Cambro-Silurian limestones and dolomites. At the exposure on Tavern Creek the formation is at least 60 feet deep and includes blocks 18 feet long. The Cambro-Silurian limestone dips toward the sink for 150 feet on either side. A cistern at Mr. Ramsey's follows a joint filled with Saline Creek cave-conglomerate 18 feet into a filled cave-gallery 11 feet across. The bowlders of the Saline Creek cave-conglomerate are noticeably local in origin, and are not only too large to have been transported by any streams possible with the supposed topography, but many of them are of such soft material that they could not have been carried far. The composition of the shales corresponds in a general way in lime and sand content with that of the surrounding rocks.

In consequence, it is inferred that these solution cavities were

filled partially by an in-washing of the surrounding soils, and partially by the caving-in of walls of the sink-holes and caves due to sapping by differential solution.

The unconformity between the Mississippian and Pennsylvanian is widespread throughout Missouri.[1] On the north slope of the Ozarks the unconformity is shown by (1) basal conglomerates, (2) discordance of bedding, and (3) general field relations, the Saline Creek cave-conglomerate being deposited on both the Burlington limestone and the Cambro-Silurian formations.

Deposition of the Coal-Measure shales.—The deposition of the Saline Creek cave-conglomerate continued until the region subsided practically to sea-level. Then began the deposition of the Coal-Measure shales. Clay washed into those depressions not filled by the Saline Creek cave-conglomerate. At times muck with a small clastic content was deposited, later to consolidate into cannel coal. The sink-holes clogged up with clay became fit sites for swamps. Coal beds 30–40 feet thick resulted (McClure Prospect 32 feet, Knowall 35 feet). Locally the sea encroached on the land, and argillaceous, fossiliferous limestones were deposited. That the basins of deposition were very local is shown by the dissimilarity of the rocks of neighboring Coal-Measure basins and the impossibility of correlating individual strata.

At the Republic Mine the following is a section from the underlying Jefferson City (Cambro-Silurian) formation up:

28 feet bituminous coal and shale interlaminated.

10 feet argillaceous limestone, fossiliferous — *Productus semireticulatus.* *Productus cora.* *Spirifer cameratus.* *Spirifer rockymontanus.*

4 feet more or less calcareous shale.

4 feet variegated chert, fossiliferous.

At the William Shelton Prospect, three miles away, the succession up from the same formation is:

50 feet shale, grading into

40 feet cannel coal.

Many equally striking cases might be cited.

[1] *Missouri Geological Survey*, Vol. VII, p. 438.

The Coal-Measure shales were deposited in sinks, enlarged joints, and cave-galleries—a fact indicated by their small area and relatively great depth. The Knowall Prospect penetrated 85 feet of Coal-Measure shale. Four drill-holes in the immediate vicinity penetrated only the Cambro-Silurian dolomites. A shaft in the Gageville Mine passed through 50 feet of Cambro-Silurian dolomite and then 10 feet of Coal-Measure shale, the contact being very irregular (Fig. 2). This appears to be a cave-gallery, and may con-

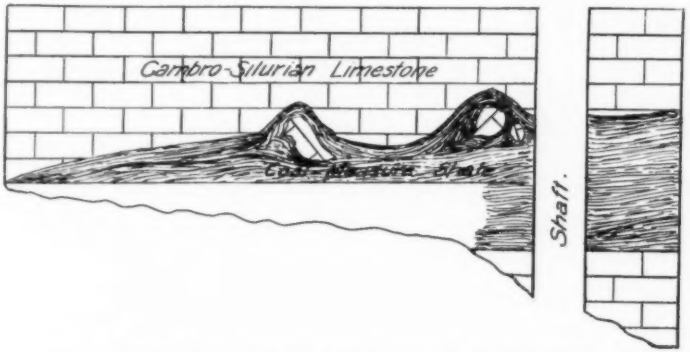

FIG. 2.—Cave-gallery filled with Coal-Measure Shale, Gageville Mine.

nect with another shale outcrop in the valley below. Coal-Measure shale occurs in a pocket 50 feet in diameter in a valley at the Son Prospect. On the hillside a shaft passed through 4½ feet of Cambro-Silurian dolomite into the shale (Fig. 3). Further evidence is the fact that the Cambro-Silurian dolomites dip, as a rule, toward the shale outcrops, often as much as 30°.

Deposition of the Graydon sandstone.—The exact time-relations between the Coal-Measure shale and the Graydon sandstone is as yet not certain, but the weight of evidence seems to make the Graydon sandstone the younger. However, the two may have been contemporaneously deposited in various parts of the country, or the sandstone may have been deposited at two or more times.

The Graydon sandstone exposures rest on the Burlington limestone and on the Cambro-Silurian formations. In the little dissected plain it occurs in many small round areas; in the more dissected

regions the exposures are fewer, possess a trail-like form, and are largely confined to valleys. From the latter conditions we infer that in the vicinity of the river, erosion has removed all but the Graydon sandstone deposited in deep gulches. These again seem "resurrected" valleys. The inclosing Cambro-Silurian walls are undisturbed, and seem to delimit normal erosion valleys.

The Graydon sandstone appears to have been deposited upon a surface somewhat like the present, with the greatest dissection in the vicinity of the Osage River. If important valleys of Graydon age had existed in the upland, we should find in this little dissected

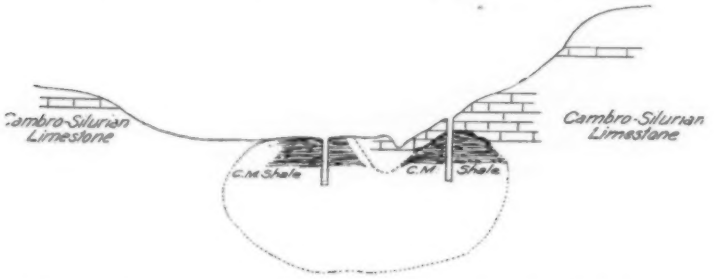

FIG. 3.—Cross-section—Son Prospect. Dotted line shows hypothetical extent of Coal-Measure shale.

portion of the uplift sandstone outcrops corresponding to them. If in the vicinity of the Osage the streams had run counter to the present channels, we would expect the resistant Cambro-Silurian rocks to preserve more filled channels crossing the present divides.

Cross-bedding and pebbles occur throughout the sandstone, and so deposition apparently kept pace with gradual depression. The first beds were perhaps deposited in estuaries, while later the whole land may have been submerged. From the probable geography of the time it may be suggested that the sand came from the south or southeast. From its lack of felspathic material, it was doubtless derived from the older Cambro-Silurian sandstones, and not from the granites of southeast Missouri.

After the deposition of the Graydon sandstone the land was again uplifted.

RÉSUMÉ.

On the north slope of the Ozark uplift the Burlington (in places the Chouteau) limestone rests unconformably upon the Cambro-Silurian formations, and the Pennsylvanian formations, in turn, rest unconformably upon the Burlington limestone and the Cambro-Silurian rocks. During the late Mississippian period, solution was unusually active, and the Saline Creek cave-conglomerate and Coal-Measure shale lie largely in solution cavities, developed previous to their deposition. The Graydon sandstone, when it rests on Cambro-Silurian rock, occupies normal erosion valleys. The present position and extent of the Carboniferous deposits is determined by several factors, among which the pre-Carboniferous and inter-Carboniferous land surfaces and post-Carboniferous erosion are important.

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ECLOGITES IN CALIFORNIA.[1]

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EUROPEAN ECLOGITES.
CALIFORNIA ECLOGITES.
San Martin.
Calaveras Valley.
Tiburon.
San José.
OREGON ECLOGITES.
CONCLUSION.

THE term "eclogite" was first introduced into the geological literature of Europe in 1822 by Haüy in his *Traité de mineralogie*, in which he gave the name to a rock composed chiefly of green augite and garnets. In the present paper the name is applied to a rock derived from some eruptive and bearing garnets in a matrix composed essentially of some form of augite, or of hornblende, or of both augite and hornblende. The various secondary minerals are given in the descriptions that follow. The term eclogite has proved useful, and the rock has evidently been an interesting one to European petrographers, for as far back as 1884 Lohmann[2] gives two pages of bibliography as an introduction to his paper on eclogites. Since then many articles have appeared in English and continental journals, the most recent being the excellent paper by Hezner,[3] which gives a discussion of the petrographical relations of eclogites and amphibolites found in the Tyrol Alps, with a bibliography of over seventy references. Hezner's article was received after the present paper was written, and although some few extracts from it have been inserted, the special student of these rocks is referred to the original article for the full details of this important contribution to the subject.

[1] The writer is under obligations to Dr. J. P. Smith, of Stanford University, for suggestions and advice.

[2] "Neue Beiträge zur Kenntniss des Eklogits vom mikroskopischen, mineralogischen und archäologischen Standpunkt," *Neues Jahrbuch für Mineralogie, Geologie und Palæontologie*, Vol. I (1884).

[3] "Ein Beitrag zur Kenntnis der Eklogite und Amphibolite," Tschermak. Mineralogisch-petrographische *Mitteilungen*, Vol. XXII (1903).

Hitherto, so far as known to the writer, no rocks have been described in the country under the title of eclogites. Nutter and Barber[1] refer to them incidentally in their discussion of glaucophane schists, and Diller[2] has recently included some rocks of the eclogite type in his description of the amphibole schists of Port Orford, Ore., but without designating them by this term. A brief preliminary review of the eclogites of Europe will furnish a basis for comparison in the study of those of our west coast.

EUROPEAN ECLOGITES.

The type eclogite of Europe is described in the valuable paper of Lüdecke,[3] who gives a detailed account of the chief minerals and of a dozen rocks found in the island of Syra. Of these latter he places glaucophane eclogite as the most important. This consists of red garnets, light green omphacite, and glaucophane. He mentions muscovite, quartz, and pyrite as accessory minerals. The omphacite is a light green augite appearing in grains and in small columns, sometimes showing the augite cleavage. Under the microscope there is little or no pleochroism, bright polarization, and a high extinction angle. The garnets are rhombic dodecahedrons with rounded corners. The glaucophane is the same as that so common on the Pacific coast, and which will be described more fully later. The garnet is considered the oldest mineral; younger than that is placed glaucophane and omphacite; and youngest of all, the quartz. In the laboratory at Stanford University are small specimens of the Syra eclogite—obtained through the kindness of Mr. Diller—which very much resemble some facies of the glaucophane eclogite of Tiburon. The glaucophane is a trifle darker blue, and the garnets do not show such definite crystal forms as do those in the California rock. In his general description of eclogites Lohmann reports the occurrence of the rock in Norway, Switzerland, Austria, France, Italy, Greece, and South Africa. Lohmann's paper is mainly devoted to an account

[1] "On Some Glaucophane and Associated Schists," JOURNAL OF GEOLOGY, Vol. X, p. 738.

[2] Folio No. 89, *Geological Atlas of the United States.*

[3] "Der Glaucophane und die glaucophane-führende Gesteine der Insel Syra," *Zeitschrift der Deutschen Geologischen Gesellschaft*, Vol. XXVII (1876).

of the stone axes made from eclogites, but his bibliography and his summaries of previous geological descriptions are of great value to the petrographer. Teall[1] describes an eclogite from the British Isles. This rock has a dull green color with reddish-brown garnets. The groundmass is omphacite with intergrowths of hornblende, feldspar, and rutile—rarely with quartz and epidote. The hornblende is strongly pleochroic. The color of the **c** ray is bluish-green; **b**, deep rich green; **a**, pale yellowish-brown. Bonney,[2] under a subheading of igneous rocks, describes a massive hornblende rock that appears to be a diorite and contains many small garnets with sphene, quartz, plagioclase, and zircon as probable accessories. He concludes that the rock might be termed a hornblende eclogite.

Patton[3] describes a "Kelyphite eclogite" from Bohemia in which the garnets are surrounded by a ring or mantle usually of hornblende and feldspar. The groundmass is a complex of hornblende and pyroxene crystals. Another outcrop with striated feldspar in the groundmass he calls, not eclogite, but an eclogite-like rock. With the disappearance of the omphacite and garnets and of the kelyphite ring the structure becomes more schistose and the rock passes into ordinary hornblende schist.

The eclogites of Bavaria are described by Newland[4] as forming a series of hills extending for some fifteen miles in the Bavarian mountains. He finds that the eclogite grades over into a basic gneiss of hornblende, garnets, and feldspar, but not into the more acid gneiss. The eclogite consists essentially of omphacite, hornblende, and garnets, with the usual accessory minerals. The analyses which he gives of Bavarian eclogites are quoted later.

Traube[5] describes an eclogite in Silesia occurring with gabbro, amphibolite, and serpentine, and forming bands separated by serpen-

[1] "On an Ecolgite from Loch Duich," *Mineralogical Magazine*, Vol. IX, p. 217.

[2] "Notes on the Vicinity of the Upper Part of Loch Maree," *Quarterly Journal of the Geological Society*, Vol. XXXVI (1880), p. 105.

[3] "Die Serpentin-und Amphibole-Gesteine nördlich von Marienbad in Böhmen," *Tscherm. min.-petr. Mitth.*, Vol. IX (1887), p. 89.

[4] "Notes on the Eclogite of the Bavarian Fichtel-Gebirge," *Transactions of the New York Academy of Science*, Vol. XVI, p. 24.

[5] "Ueber ein Vorkommen von Eklogite in Schlesien," *Neues Jahrbuch*, Vol. I (1889), p. 195.

tine. The eclogite from the Tyrol Alps recently described by Hezner[1] is composed primarily of clear red garnets, commonly in rounded grains, in a groundmass of emerald-green omphacite. The garnets vary from fine grains up to the size of peas, but the crystal form is seldom distinct. Hezner considers that this eclogite is chemically a gabbro or a variation of the same magma that furnished the gabbro. Eclogite, he thinks, is formed in the greatest depths and in the higher zones amphibolite—the garnet and the omphacite being amphibolized.

The foregoing brief extracts will give some idea of the eclogites of Europe and of their probable derivation.

CALIFORNIA ECLOGITES.

Probably the most typical eclogite in California is that found in the bed of Coyote Creek, about eighteen miles southeast of San José and some six miles east of north from San Martin. The outcrop of massive rock is exposed for about twenty feet in the edge of the stream. Apparently it breaks through the shale and jasper exposed at the foot of the hill only a few feet away, but the gravel of the creek entirely covers the contact. On the opposite side of the stream, and within a hundred yards, is a large mass of serpentine, which, however, is not in contact with the eclogite. The most characteristic facies of the outcrop is that which shows a grass-green groundmass, thickly studded with dark red garnets several millimeters in diameter and showing distinctly the rhombic dodecahedron form. The faces of the garnet are fresh and shining, with clear-cut edges. The reproduction of the photograph in Fig. 1 shows the structure of the rock, but the striking effect of the red garnets in the light green groundmass is unfortunately lost.

Seams and segregations of glaucophane, sometimes bearing garnets, occur in the exposure. Prominent veins of a fine-grained reddish mineral were taken in the field for inclusions of the nearby jasper, but its fusibility, and its isotropic character under the microscope, proved it to be a compact variety of garnet. Segregations of actinolite crystals are common, and chlorite frequently occurs. Some particles of chalcopyrite are seen in the rock, and a few parti-

[1] *Op. cit.*

cles of free gold were found in the granular garnet. The rock has attracted the attention of prospectors, and it is reported that an assay showed nearly two dollars of gold per ton. In a few places there were inclusions, some 10–15^{mm} in diameter, of a reddish-brown mineral with cleavage faces giving an almost metallic luster. In the laboratory the mineral was found to be infusible and to possess a hardness

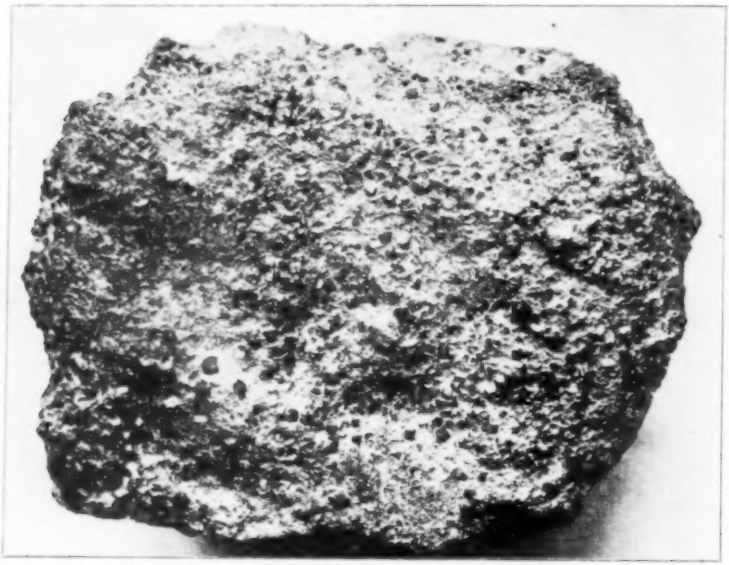

FIG. 1.—Eclogite from San Martin, Calif. Slightly reduced in size.

of over six. The streak is yellowish-brown. A determination of the specific gravity of the purest fragment obtainable gave a result of 4.154. After fusion with soda the acid solution boiled with tin gives the violet reaction of titanium. The mineral was determined as rutile—a result which the microscopic examination of a thin section confirmed.

The specific gravity of the eclogite itself varied from 3.33 to 3.58 in different fragments—apparently varying with the number of garnets included. Some of the garnets were separated from the groundmass and found to have a specific gravity of 3.68. A qualitative determi-

nation of the garnets indicates that they are the iron-alumina variety with a considerable amount of calcium.

Under the microscope the main groundmass of the eclogite is seen to be light-green omphacite, with little, if any, pleochroism. The interference colors are bright, and the extinction angle runs up to 40°. The garnets show regular outlines, and are of a pale pink color by transmitted light. Usually they are cracked, with omphacite filling the cracks. Rutile is present as a segregation in the groundmass and as inclusions in the garnets. Sphene of a light brownish color, somewhat pleochroic, and with characteristic relief, is plentifully distributed in irregular grains.

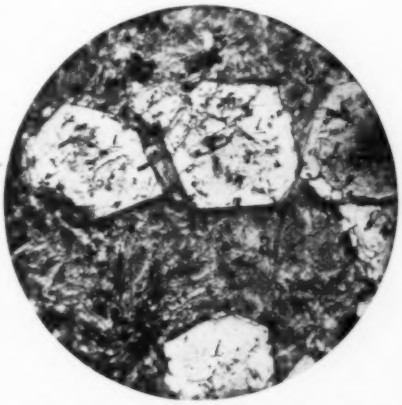

FIG. 2.—Omphacite eclogite, San Martin. × 24. 1 = garnet, 2 = omphacite, 3 = rutile.

The microphotograph in Fig. 2 shows the clear outlines of the garnets. The inclusions in them are omphacite, apatite, rutile, quartz, and sometimes chlorite. The felted groundmass is composed of small columns of omphacite. Many of the slides are practically free from glaucophane, although veins of this mineral are quite plentiful in the exposure. The glaucophane is a somewhat more definite blue than is usually described as steel-blue, and in the slide shows strong pleochroism. The color of the **a** ray is a very pale yellow; the **b** ray, a purplish violet; the **c** ray, a clear blue. The extinction angles in several sections were found to be close to 5°. The orientation is that common in glaucophane, with the **b** axis corresponding to the axis of symmetry and the **c** axis nearest to c'. In places the glaucophane grades over into a green hornblende. In one of the slides there is an irregular-shaped mineral of a light brown color and cut by intersecting cracks. It is pleochroic in tints of brown. The relief is high, and the interference colors are of the third or fourth

order. While this mineral differs somewhat from the sphene appearing in grains, it is thought to be the same, although possibly somewhat changed by decomposition.

Calaveras Valley.—This little valley is in Santa Clara county, about fifteen miles northwest from the Lick Observatory. In it are found two distinct kinds of eclogite—a light-green omphacite variety and a dark, almost black, hornblende eclogite. The first occurs at the mouth of the narrow gorge which is the outlet of the valley to the north. The outcrop is on the west side of the stream on the bank of the flood-plain, and is about a hundred feet long. On the hillside above, serpentine is found, and in the stream-bed below, shale and sandstone, with characteristic Miocene fossils.

The dark hornblende eclogite is farther upstream on the east side of the valley. The exposure is over a hundred feet in thickness, and was followed southward for more than a half-mile without finding the limit. On the upper side is a greenstone with an extensive serpentine belt lying just above. Farther upstream sandstone occurs between the eclogite and the serpentine. The eclogite appears to be a dike cutting across the Franciscan sandstone.

The green eclogite of the lower exposure varies considerably in its appearance. The garnets are sometimes small and clear-cut, sometimes 8 to 10^{mm} in diameter and without definite form. Glaucophane is also very irregularly distributed throughout the exposure. Under the microscope the groundmass is seen to be largely composed of closely packed little columns of omphacite. Much of it shows wavy extinction, as if the rock had been subjected to crushing. This is also indicated by the badly fractured condition of the larger garnets. Part of the green groundmass is probably the grass-green hornblende, smaragdite, although rather indefinite results were obtained in measuring extinction angles. Irregular light-colored sphene granules are scattered freely through the slides. A mineral with lighter color than the omphacite shows some pleochroism and very low interference colors. It was determined as chlorite, and is probably derived from the hornblende or the augite. In places it shows a bright Prussian blue interference color—according to Rosenbusch, a characteristic of the pennine division of chlorites. Glaucophane is plentiful in some of the slides and in a few instances gave an

extinction angle as high as 15° for the angle of **c** on *c'*. Small quantities of feldspar and quartz appear in some of the slides.

The relations of the glaucophane and the chlorite are interesting, as seen in Fig. 3, where the two minerals are apparently reacting in some way. Along the line of contact there is a deep blue border as indicated in the sketch. In Fig. 4, which is from the same slide, the crystal of glaucophane cuts clearly through the chlorite. The latter has evidently been sheared by some stress, and the glaucophane is a later growth. The chlorite crystal has a definite extinction angle of

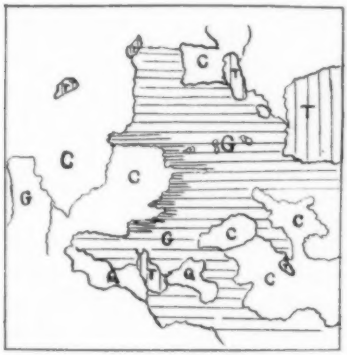

FIG. 3.

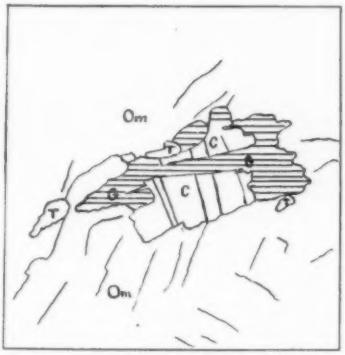

FIG. 4.

G = glaucophane, *C* = chlorite, *T* = sphene, *Q* = quartz, *Om* = omphacite

15°, which may indicate formation from hornblende, for the chlorite properly has small extinction angles or no definite extinction.

The dark hornblende eclogite in Calaveras Valley is the only one of its kind yet found in the state. Macroscopically it shows the dark hornblende with fresh cleavage faces, and with garnets plentiful in some specimens and few in others. Before the blowpipe the hornblende melts easily to a magnetic globule, at the same time coloring the flame yellow.

In the slide nearly all possible sections of the hornblende are found, as may be seen in the accompanying microphotograph. The garnets lack the clear outlines so noticeable in the San Martin eclogite. Some of the hornblende crystals are bordered with glaucophane, which appears white in the photograph. The hornblende

is strongly pleochroic as follows: **a**, light greenish-yellow; **b**, olive-green; **c**, greenish-blue. The orientation is the same as in glaucophane the **b** axis corresponding to the axis of symmetry and the extinction angle of **c** on c' is nearly 25°. This angle is unusually large for hornblende. Hintze,[1] however, gives some still greater. His table of extinction angles for hornblende varies from 16° to 27° 30′, the percentage of Al_2O_3 varying at the same time from 1.89 to 20.73. A black hornblende, pargasite, has an extinction angle, **c** on c', of 24° 30′ the Al_2O_3 varying from 11.92 to 13.75 per cent. A light green pargasite is given with a slightly higher extinction angle, and also a higher percentage of alumina. The pleochroism is not given in the same table, but a few pages later he gives the following for a light pargasite: **a**, greenish-yellow; **b**, emerald-green; **c**, greenish-blue. It should be noted that pargasite is sometimes blue and appears to be usually soda-bearing, as the analyses quoted by Hintze show.

FIG. 5. — Hornblende eclogite, Calaveras. × 24. 1 = garnet, 2 = quartz, 3 = hornblende, 4 = rutile, 5 = glaucophane.

Blasdale[2] describes a hornblende from the vicinity of Berkeley with a pleochroism of **c**, bluish-green; **b**, yellowish-green; **a**, lighter green. The extinction angle is given as 14° 34′, and the percentage of soda 2.45 and of alumina 2.05–3.45. The glaucophane in the Calaveras hornblende eclogite is along the borders of the hornblende crystals, and is apparently of a later growth. A similar instance of such a change is described by Cross,[3] who found blue hornblende upon the ends of a brown hornblende occurring near Silver Cliff, Colo.

[1] *Handbuch der Mineralogie*, Vol. II, p. 1188.

[2] "Contributions to Mineralogy," *Bulletin of the Department of Geology, University of California*, Vol. II, p. 328.

[3] "Some Secondary Minerals of the Amphibole and Pyroxene Groups," *American Journal of Science*, Vol. XXXIX (1890), p. 359.

The garnets in the hornblende eclogite have a fresh, clear color, and show little sign of change, but they are much cracked. Small quantities of feldspar and of quartz are found in the different slides. An opaque irregular mass shows by reflected light a yellow center and a black border. It is undoubtedly pyrite surrounded by iron oxide.

A hand specimen of eclogite has recently been sent to the writer by W. D. Smith, who collected it at a point some four miles south of east from the Calaveras exposure described in this paper. It carries coarse red garnets up to a half-inch in diameter, some of them showing well the rhombic dodecahedral form. The groundmass seems to be chlorite, glaucophane, and omphacite. The eclogite most resembles the San Martin variety, but is not quite so fresh in appearance. No igneous rock is reported from the vicinity.

Tiburon.—In addition to the interest attached to this locality because of the discovery of lawsonite, the peninsula of Tiburon in San Francisco Bay is noteworthy from the number of outcrops of eclogite found there. Much of the rocky knoll near Reed Station, where the lawsonite occurs, is eclogite of the glaucophane-omphacite variety. The minerals in this rock have been described by Ransome.[1] On the top of the hill above the lawsonite are two outcrops of eclogite occurring in the serpentine area. These have more omphacite than glaucophane, while on the slope of the hill beyond a glaucophane eclogite occurs that is almost free from omphacite. The slides from the first outcrop were mainly selected to show lawsonite, and so the proportion of that mineral appears unduly large. The matrix is usually composed of small allotromorphic crystals of a grass-green color intergrown with glaucophane. The green mineral shows no pleochroism in most cases. The extinction is frequently wavy, but where it admits of measurement the maximum angle is close to 40°. The mineral is identified as omphacite, with a probability that a portion of the green matrix is hornblende. In some cases the garnets are almost entirely replaced by chlorite; in others there is a celyphite border of the chlorite. In one instance the garnet has a celyphite border of mica. Mica is very common in these slides, and is determined as margasite by Ransome, to whom reference is made for the full description of the associated minerals.

[1] "On Lawsonite, a New Rock-Forming Mineral," *Bulletin of the Department of Geology, University of California*, Vol. I, p. 311.

San José.—The hills just south of the Oak Hill Cemetery are composed largely of masses of peridotite and gabbro with the resulting serpentine. On one slope there is an outcrop of grayish-green rock that is in part eclogite. The garnets are small and sometimes form veins of the compact granular variety of this mineral. In the slide there is much glaucophane and chlorite, the latter frequently exhibiting the Prussian blue interference color. A few crystals of feldspar are found, and also considerable mica and sphene. The outcrop is of interest mainly because of its occurrence in an area of igneous rocks.

Eclogites from other localities.—Slides and hand specimens from Sonoma county have been studied in the laboratory. They are of the glaucophane type of eclogite and have the usual accessories. Nutter and Barber[1] state that the eclogite occurs in large masses associated with schists. Melville[2] describes a bluish glaucophane schist from Mount Diablo with streaks of green and with innumerable garnets. No slide or hand specimen has been available. Among the rocks of Catalina Island, W. S. T. Smith[3] describes a garnet amphibole of greenish or brownish hornblende and carrying roughly rounded garnets. Rutile is mentioned as an inclusion. The term "eclogite" is not used in his account. A specimen of eclogite from Anacapa Island, some sixty miles to the northwest of Catalina, is in the Law collection, but there is no note as to its occurrence.

OREGON ECLOGITE.

Although the locality is outside of California, fuller reference should be made to the rocks described by Diller from Port Orford. He finds glaucophane-, actinolite-, mica-, and epidote-schists all grading into each other and all having the same origin. Garnets are sometimes found in abundance. These schists he thinks are derived from rocks of the basaltic type. In many places the original rock is changed to plagioclase hornblende rock. Usually the pyroxene alters to a green hornblende, but sometimes to a blue—giving the

[1] *Op. cit.*, p. 740.

[2] "Notes on the Chemistry of the Mount Diablo Rocks," *Bulletin of the Geological Society of America*, Vol. II, p. 403.

[3] "The Geology of Catalina Island," *Proceedings of the California Academy of Science*, Geology, 3d ser., Vol. I, p. 62.

glaucophane schist. While the alteration is generally complete, he found a volcanic neck where on one side the change is not entire, and under the microscope augite is seen changing into glaucophane. The feldspar has changed chiefly to epidote. Some green hornblende and chlorite are present. An examination of several slides—kindly loaned by Mr. Diller to Dr. J. P. Smith—shows that part of them may be classed as glaucophane eclogites. One specimen from Winston's Bridge is essentially glaucophane and garnets—the latter $2-3^{mm}$ in diameter. Mica, chlorite, sphene, and epidote are also present. An analysis of this rock without the garnets, as given by Washington,[1] is included in the table herewith.

CONCLUSION.

The question of the derivation of eclogites and of their place in the series of metamorphic rocks is both interesting and difficult. In the absence of direct proof for any special instance at hand opinions as to the igneous origin of a metamorphic rock should be given with due reservation. It seems to be well established that both igneous and sedimentary rocks sometimes grade into schistose forms that appear to be indistinguishable on first examination. From the evidence now at hand the writer would conclude that the San Martin and the Calaveras eclogites are derived from basic eruptives of the gabbro type. This derivation is indicated by their massive and irregular appearance in the field as well as by the general field relations.

The occurrence of the San José eclogite in the Oak Hill area of igneous rocks indicates that we have there merely the modification of a rock derived from the same magma as the basic eruptives that form the hills. The igneous origin of the San Martin eclogite is also indicated by the chemical analysis. As may be seen in the accompanying table, the silica is only slightly over 44 per cent.—which indicates derivation from some very basic eruptive. The percentage of silica is very close to that given by Hezner in the two analyses which he has made. Hezner thinks that his analyses show well the normal chemical composition of eclogites. The table of analyses here given should be supplemented by additional work on the California eclogites, but it is at least suggestive in the comparisons which it affords.

[1] "Study of the Glaucophane Schists," *American Journal of Science*, Vol. CLXI.

ANALYSES OF EGLOGITES AND RELATED ROCKS.

	1	2	3	4	5	6	7	8	9
SiO_2	44.15	44.06	46.26	57.10	55.00	48.81	46.07	46.88	41.20
Al_2O_3	10.18	17.63	14.45	11.66	13.54	16.25	15.35	19.16	15.40
Fe_2O_3	11.92	3.40	4.41	2.84	2.74	6.00	3.61	} 10.63	2.49
FeO	13.04	9.96	5.82	3.22	3.37	7.48	9.87		4.67
MgO	6.18	7.19	11.94	6.37	10.21	7.12	7.83	9.48	15.51
CaO	4.51	11.58	11.66	13.80	12.09	9.72	4.37	13.37	12.26
Na_2O	5.11	2.92	2.45	2.21	2.10	2.64	3.22	.....	3.44
K_2O	2.09	0.91	1.51	0.81	0.50	0.46	2.68	.....	2.49
H_2O +110°	0.95	0.17	.....	0.54	0.32	0.12	4.25	.....	1.31
H_2O −110°		0.12	1.10				0.16	.....	
CO_2	.....	.....	.....	.....	.....	.....	1.05	.....	.....
TiO_2	Tr	2.29	0.28	.....	.....	.....	1.63	0.18	0.43
									Fl.
MnO	.....	.....	.....	0.31	0.20	0.43	tr.	.....	1.86
Total	99.31	100.23	99.93	98.86	100.27	99.03	100.09	99.67	.....

1. San Martin eclogite, Analysis by C. B. Allen (kindness of Dr. J. P. Smith).

2 and 3. Tyrol eclogites. L. Hezner.

4, 5, and 6. Bavarian eclogites quoted, by Newlands.

7. Glaucophane (eclogite?) from Oregon. Washington.

8. Gabbro. Oak Hill, San José. Analysis furnished Dr. J. C. Branner by U. S. Geological Survey.

9. Pargasite, steel-blue to black. Hintze.

The opinions of Diller, Bonney, and Traube as to the igneous origin of certain eclogites have already been quoted. Harker[1] gives a brief description of eclogites, and quotes Fouqué and Lévy as to a French hornblende eclogite that is "a local modification of a diorite."

In connection with the igneous origin of eclogites, the writer tried the experiment of fusing several specimens in a coke assay furnace. The crucibles were kept at the highest temperature of the furnace for about three hours, and then the drafts were closed and the whole allowed to cool slowly overnight. The eclogites fused easily to homogeneous lava like obsidian. Under the microscope this showed a practically uniform isotropic character. With a high power points showing double refraction were found scattered through the slide, but no detail could be made out.

A list of the constituent minerals found in California eclogites, and a brief mention of their properties as they are found in these rocks, will unify the preceding descriptions.

First among the essential minerals is garnet. The color is usually a dark red in the hand specimen. In size the garnets vary from 2 to 5^{mm}, for the well-developed dodecahedrons of the San Martin eclogite,

[1] *Petrology for Students*, 1887, p. 329.

to 10 or 12^{mm} for the rounded forms in some of the Calaveras exposures. Of the essential minerals garnet is evidently the oldest, for in the cracks are found glaucophane, omphacite, and hornblende. Yet these latter minerals are also found as inclusions together with rutile, apatite, feldspar, and quartz. Inclusions of glaucophane may be paramorphs of inclusions in the original matrix. Qualitative tests indicate that the garnets contain iron, calcium, and aluminum.

Omphacite, the light green augite, usually occurs in aggregates of prismatic crystals, some a $\frac{1}{2}^{mm}$ in length and without definite termination. The bright polarization, absence of pleochroism, high extinction angle, and occasional augite cleavage serve to distinguish it. Lüdecke deduced the formula (CaFe) SiO_3MgSiO_3 from his chemical analyses.

Smaragdite is an emerald-green actinolite that in the eclogites much resembles omphacite, being distinguished from it by the hornblende extinction angle and usually by pleochroism. The blue soda hornblende, glaucophane, has the marked pleochroism already given and an extinction angle of **c** on *c'* varying from 5 to 15°. It seems to be derived from hornblende in the eclogite in Calaveras Valley—at least the hornblende crystals are bordered by it. Diller has already been quoted as to the change of pyroxene to glaucophane in the Port Orford rocks, some of which are here classed as eclogites. The analyses of some of the igneous rocks considered show that they contain enough soda for this change to occur without the addition of elements from the outside. The hornblende in the Calaveras eclogite show soda in the qualitative test, and also has a general resemblance to glaucophane in its pleochroism and in its orientation. Hintze has already been quoted in regard to a black pargasite that seems to agree closely with the Calaveras variety of hornblende in pleochroism and extinction angle. This pargasite contains, according to his analysis, 3.44 per cent. of soda—which is more than the percentage of soda in the Port Orford glaucophane.

Both garnet and hornblende are found replaced by chlorite—pale green in color, and showing low interference colors except in the pennine variety, which shows Prussian blue between crossed nicols.

Mica seems to be absent from the Calaveras slides and is found in very small quantities in those from San Martin. In the Tiburon

eclogite margasite is very plentiful and has been fully described by Ransome, as already cited. White mica, probably paragonite, occurs in the San José eclogite and in that from Sonoma county.

Titanite, or sphene, is thickly distributed in some of the slides in very minute grains. It is a very light brown color and pleochroic in tints of that color. Rutile in large crystals 10–15^{mm} in diameter is found only at San Martin, but it is found somewhat less freely than sphene in the shape of small irregular grains in nearly all the slides. It is yellowish to reddish-brown and somewhat pleochroic, and has very high relief.

Epidote is rather irregular in its occurrence. When found, it exhibits lower interference colors than those usually described. Ransome[1] thinks that this is accounted for by a smaller proportion of iron, and that in chemical constitution the epidote may grade over into zoisite. Zoisite and cyanite were seldom found. Pyrite appears occasionally, but not so frequently as was expected from the description of the European eclogites.

All of the above minerals are possibly secondary in their occurrence in eclogites. The occasional feldspar and quartz may be the only minerals remaining unchanged from the original rock. The garnets and the epidote have probably taken up the line of the original feldspar, while the soda is to be found in the glaucophane or in the pargasite variety of hornblende.

While the use of the term "eclogite" is now fairly definite, there is still a question of some limitations in its application. In constitution the rock must contain garnets in a matrix of omphacite, glaucophane, or hornblende, or of some mixture of these minerals. Hezner evidently would insist that there must be omphacite, for even with about equal proportions of hornblende he drops the term "eclogite" and uses "eclogite-amphibolite." The common accessory minerals are sphene, rutile, epidote, apatite, zoisite, cyanite, feldspar, and quartz. While some metamorphosed sedimentary rocks approach eclogites in composition, the tendency seems to be to restrict the term to rocks that are clearly of igneous derivation.

RULIFF S. HOLWAY.

BERKELEY, CALIF.

[1] *Op. cit.*, p. 310.

Editorial.

It is always a pleasure to note a graceful expression of appreciation of long and faithful endeavor to promote our science—doubly so when this service has been given in a singularly quiet and modest way, without any apparent realization of its true merits.

At a recent alumni dinner of the State University of Iowa, the former students of Professor Samuel Calvin, to the number of over two thousand, united in the commemoration of the completion of his thirtieth year as professor in that institution. The recognition took the form of a costly silver loving-cup, designed especially for the purpose of symbolizing the scientific achievements of the recipient. The cup is a classic Greek vase, sixteen inches in height, and stands on a base of serpentine five inches high. It is adorned with casts taken directly from fossils, with a drainage map of Iowa, with crossed geological hammers, a microscope, and the more conventional spray of laurel, owl of wisdom, and torch of learning—all in relief. One side bears an appropriate inscription in raised letters.

Professor Calvin was elected to the chair of natural history in Iowa's university thirty years ago. The chair has since been subdivided into four distinct departments, Professor Calvin retaining the department of geology. As well known to the profession, he has been state geologist of Iowa during the last twelve years, and an admirable series of reports is appearing under his administration.

Reviews.

Catalogue of the Ward-Coonley Collection of Meteorites. By Henry A. Ward. Chicago, 1904.

The third catalogue of this collection has been issued within four years as a consequence of its rapid growth from 424 falls in 1900 to 603 falls in 1904. The weight of the present collection aggregates 2,495 kg. It contains 241 falls of siderites, 28 of siderolites, and 334 of aerolit s. The number of specimens is about 1600. The greater number of falls is from North America and Europe, but there are considerable numbers from Asia, Africa, Australia, Sandwich Islands, and South America.

The catalogue is prefaced by a statement of the method by which the collection was gathered together and an account of the most noteworthy specimens. Under the entry of each fall is given the date and locality of fall, the name and description of the meteorite, the reference to the published description, together with the weight of the chief piece and the total weight of the material in the collection.

There is in addition an alphabetical list of all known meteorites, and another giving their geographical distribution, arranged according to countries. This is followed by a statement of the latest revised classification of meteorites by Dr. Aristides Brezina, of Vienna, giving the system, composition, and name, with the list of meteorites belonging to each division.

The Ward-Coonley collection also contains a library of over 800 titles, besides some minerals characteristic of meteorites, a small collection of their sections, specimens of terrestrial iron, and a series of casts of meteorites. The collection is at present exhibited in the American Museum of Natural History in New York city.